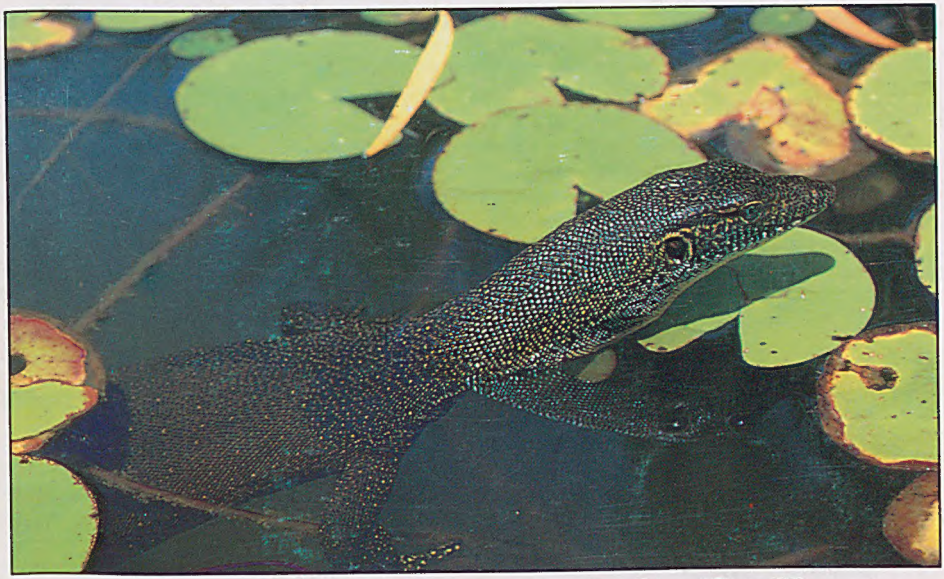
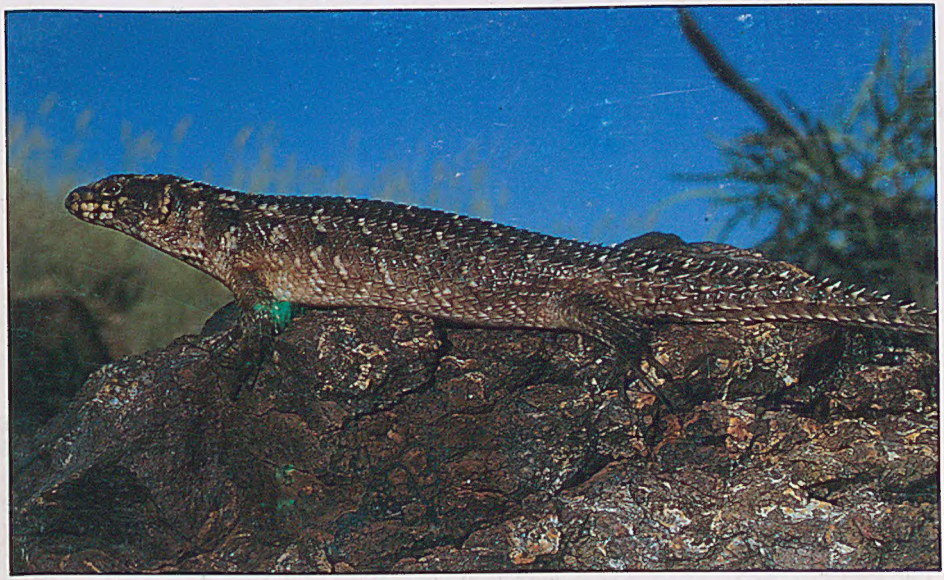
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HERPETOFAUNA

Volume 25 Number 2 December 1995



Mertens' water monitor (*Varanus mertensi*) from King Edward River, WA.
See paper on page 4. (photo: H. Cogger)



Hosmer's skink (*Egernia hosmeri*) from the Mount Isa area
See paper on page 8. (photo: G. Shea)

Herpetofauna is published twice yearly by the Australasian Affiliation of Herpetological Societies. The Affiliation started on an informal basis in 1974 and was formally established in 1977. It is the result of a formal agreement between member societies to participate in cooperative activities.

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REFLECTIONS AND NEW VISTAS AS A FRIEND MOVES ON - HAL COGGER RETIRES

When people retire it is a common practice for a plethora of superlatives, describing hitherto covert virtues, to be unleashed by well wishers in euphoric fervour, then to be forgotten and not revisited till their wake. Hal Cogger retired recently from his position as Deputy Director of the Australian Museum, however any such artifice is quite unnecessary in speaking of him, rather, one must be overly selective, as his achievements are many.

There are at least four reasons for me to comment on the occasion of Hals most recent rite of passage:

- To celebrate, for its own sake, this milestone in the career of an elder of Australian and international herpetology and the achievements that built that status.
- To remember his decades of encouragement of herpetological interest groups, particularly the AHS, and acknowledge the active support he has given non professional herpetologists, recognising their many significant contributions both in writing and through personal advocacy.
- To perpetuate the inspiration of a disciplined man's outstanding career from Cadet Preparator to Deputy Director of one of the world's great museums.
- And, more personally, to pay tribute to a most genuine and gracious friend whom I hold dear.

As a young man Hal was active in the fledgling Australian Herpetological Society and was featured being 'bitten' by a Brown Snake in a film they produced called 'Strange Fascination'. An early paper, written jointly with Alex (Rusty) Holmes, concerned thermoregulation in a Carpet Python and was an excellent example of the sort of investigation that could be conducted simply by any enthusiast with a bit of vision. It is the vision, tempered by self discipline that makes the difference, I suppose. He has continued as a valued friend and confidant to many members of the AHS and Frog and Tadpole Study Group while on numerous occasions Hal's talks enthralled their members. I particularly remember the time that, after field work in New Guinea, a Pitted Shelled Turtle hatched in his hand as he addressed an AHS meeting. Hal was invited to become, and for many years has been, the Patron of the AHS.

Hal started his working life in 1952 as one of four Cadet Preparators at the Australian Museum who, with Joseph Kingsley, Head Preparator, and three Preparators, made up the Department of Preparation. One of the Preparators was Roy Mackay, founder of the AHS. Hal's first day, the story is told, was spent under the close supervision of Joe Kingsley, selecting a pocket knife. None of those Hal chose met with Kingsley's approval, leaving the sixteen year old Hal wondering why his superior had brought him along - it would have been simpler to have bought the knife and then given it to his new member of staff. The pocket knife was important. It was to be sharpened every morning and it was to be carried at all times. One could never tell whether at midnight one might find a bird that needed skinning! The Government issue pocket knife was also to be the only tool of trade used, as Hal discovered when Kingsley caught him using a scalpel, confiscated it and let him know that he would be dismissed if he ever used one again.

With hard work and determination Hal undertook part time studies - first at Tech to gain his Leaving Certificate (comparable to the HSC today) and later at the University of Technology (now the University of NSW) for a part time science course. In 1954 Dr JW Evans, to whom much of the Australian Museum's present status is due, was appointed Director. He interviewed each member of staff and offered Hal an opportunity to become a science trainee - in the Entomology Department. Hal replied that he would rather be a Preparator than an Entomologist. Thank Heavens for the rashness of youth! Evans, who was to become Hal's mentor, later presented the chance that the young man really wanted - a traineeship in Herpetology. This meant that most of his time was spent in study and university vacations working at the Museum. Resourcefully, to supplement his income, he made up and sold artificial sea water for marine aquarium use. In 1960 he graduated from Sydney University, after which he was appointed to the Department of Birds, Reptiles and Amphibians with Allen Keast (an ornithologist who had succeeded JR (Roy) Kinghorn on his retirement in 1956). Hal obtained an MSc, again at Sydney University, and in 1961 was promoted

to become Assistant Curator of the Department of Ornithology and Herpetology, and a Curator in 1963. In 1967 Hal took two years leave to further his study of an arid zone lizard, the Mallee Dragon, *Ctenophorus fordi*, towards a PhD, on the understanding that he work at the Museum one day a week to keep the Department running. An award of Doctor of Philosophy was made in 1970 by Macquarie University. In 1976 Dr Cogger was appointed Deputy Director of the Australian Museum, a position he held till his retirement.

Research interests have been broad, including sea kraits and Fijian iguanas, but Hal's principal involvement has been in arid zone reptile ecology and zoogeography.

Hal's eminent international standing is unquestioned - Vice President of the International Commission on Zoological Nomenclature, Member of the Executive of the First World Congress of Herpetology, and so on. Within our own country he has occupied several prestigious positions and is Chair of the Advisory Committee of the Australian Biological Resources Study. Hals best known book, 'Reptiles and Amphibians of Australia', first published in September 1975, has remained through each edition the ultimate handbook for those interested in Australian reptiles and frogs. Amongst many, I will mention one other notable published achievement, 'The Action Plan for Australian Reptiles', of which he is the senior author. This is a work which should be thoughtfully considered by each of us, a treatment of the 50 or so reptile species of conservation concern with costed plans to slow or reverse the effects of threatening pressures.

Hal was amongst the principals who established the Peter Rankin Trust which awarded grants to support research by young herpetologists. Peter Rankin was a gifted young man whom Hal and others had nurtured and who, soon after graduating, died while collecting in New Caledonia. This tragedy perhaps highlights Hal's intense interest in encouraging young scientists.

I could write further of his authorship, his photography, his assistance to promising herpetologists and other achievements, all significant facets of his work, but above all of that, what stands out to me are his qualities of sincerity, wisdom, commitment and humility. Surely all who know him and have been encouraged by him, and those who just know of him through his work, would join in wishing Hal ongoing and outstanding success, not in retirement, but in his new phase of his continuing career.

David B. Millar

OBITUARY

Shane Gow 1959 - 1995

It is with great sadness that we have to inform our readers of the death of Shane Gow on the 7th November, 1995. Shane was known primarily in Sydney for his skills in keeping and breeding frogs. Years of herpetological excursions and captive care of frogs, starting in his childhood in Hobart, provided him with an immense general knowledge on the subject. Although Shane published three papers in *Herpetofauna* it is a tragedy that much of his knowledge on the breeding behaviour of frog species has been lost. He did not feel at liberty to disclose many of his findings due to the draconian restrictions on the keeping of tadpoles and frogs in the current NSW fauna legislation.

With his passing we lose a great mate who would always be ready to go out and observe frogs. His ability to identify tadpoles (or to raise them until he was certain of the species' identification) will be sorely missed, just as it was greatly envied. Shane's notebooks and specimen collection will be lodged in the Australian Museum.

Our condolences go to his families in Sydney and Hobart.

PUBLICATIONS

Notes on the captive breeding of *Litoria alboguttata* (Anura: Hylidae). *Herpetofauna* 21 (2): 34.
Mating behaviour of *Litoria lesueuri* (Anura: Hylidae). *Herpetofauna* 23 (2): 6-9.
Rapid recovery of reproductive condition in a female *Litoria Infrafrenata* (Anura: Hylidae). *Herpetofauna* 25 (1): 28-29.

Karen Thum.

THE SUCCESSFUL BREEDING OF MERTENS' MONITOR LIZARD, *VARANUS MERTENSI*, GLAUERT 1951.

Bernd Eidenmüller, Griesheimer Ufer 53, 65933 Frankfurt/M, Germany
Rudolf Wicker, Zoologischer Garten Frankfurt/M., Alfred-Brehm-Platz 16, 60316 Frankfurt/M., Germany

INTRODUCTION

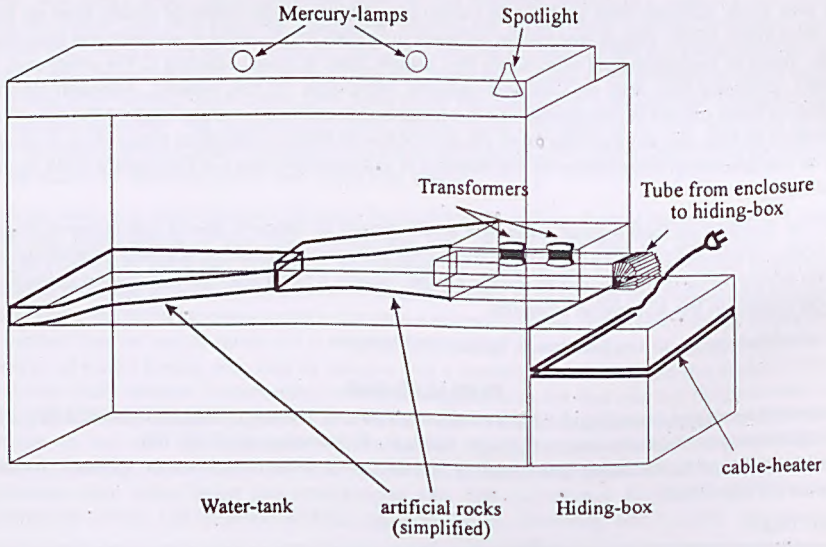
Mertens' monitor (*Varanus mertensi*) is a semi aquatic varanid from tropical northern Australia (Bustard 1970, Cogger 1992, Ehmann 1992, Hoser 1989, Keast 1959, Mertens 1958), and grows up to 1.2 m in total length. With highly compressed tails and upward-directed nostrils, they are well adapted to their aquatic habitat. They are found in both lakes and rivers, giving them a discontinuous distribution. The phenotype varies at different locations, with specimens from Mary Kathleen Dam near Mt Isa having a more round-shaped snout than those from the Kimberley region (personal observation, BE), but no subspecies have been designated. There are few observations of the behaviour in captive specimens (Murphy & Lamoreaux 1978, Schürer & Horn 1976) outside Australia. One captive breeding was reported (Brotzler 1965) at the Stuttgart Zoo, where five young hatched.

Reproduction of our animals started in 1988, after the animals were moved into a specially constructed terraria (Eidenmüller 1990). They have reproduced nine times resulting in 58 hatchlings from 60 eggs, and the 10th and 11th clutches are still incubating (May 1995, the first two offspring from clutch no. 10 hatched after 225 days). On one occasion, two embryos developed in a single egg, but only one hatched alive (Eidenmüller & Stein 1991).

HOUSING

The construction of the terrarium is shown in Figure 1. It measures 150 x 60 x 110 cm, is made of glass, with sliding doors in the front. Artificial epoxy-painted rocks are cut from styrofoam, glued together to form appropriate basking and hiding sites. Sand was salted onto wet epoxy and allowed to dry, producing a rock-like texture. While other varanids tend to lose claws on such substrates, this has not been the case for *V.mertensi* in our care. The water is heated by a 300W glass-heater to a temperature of about 28°C. A small submerged EHEIM-filter is used to keep the water moving.

Figure 1: Construction of the enclosure for *Varanus mertensi*



Illumination is provided by two 50 Watt mercury lamps, and the air is heated by a 60 Watt spotlight suspended over one side of the terrarium. Additional heat comes from the mercury lamp transformers, housed in a container beneath the basking place. A seasonal variation in illumination and temperature is not made. The animal enclosure is positioned opposite a large window directed to the south, so the monitors can register central European day length and light intensity variation.

There is a box attached outside the main terrarium, measuring 35 x 60 x 40 cm, where the lizards can hide and lay eggs. Access is from a hole cut under the styrofoam rocks close to the heat lamp. Damp sand is used as box substrate. A 30 W heat cable, which is fixed inside the box with silicon, is used to heat the sand from above (see Figure 1), to simulate an artificial temperature gradient.

FEEDING

The natural diet of *Varanus mertensi* is made up primarily of small crabs, various insects, fish, frogs and reptile eggs (Losos & Greene 1988). Captive monitors are fed crickets, cockroaches, adult mice, small fishes, and occasionally crabs, thus recreating the natural diet as closely as possible. From October until May, lizards are fed once weekly, and only monthly during the low activity period between May and early October. Mice are injected with Tricrescovit® vitamin supplement (IFFA Merieux) at 0.5-1.0 ml per mouse. Insects are dusted with Korvimin ZVT® vitamin-mineral powder.

REPRODUCTION

Sexes were determined by observing the male evert his hemipenes, and through endoscopic examination. The pair are usually housed together. The following describes the first reproduction. All subsequent breeding successes happened in the same manner. All breeding data are listed in Table 1.

Prior to mating the male showed no special courtship behaviour, except head bobbing, which frequently occurs in the breeding season. The copulation usually starts in the water, and subsequently is continued when they emerge on land. Copulation lasted approximately 10 minutes. We could observe only one single copulation during one reproduction cycle.

Eighteen days after observed copulation the male was removed from the enclosure to reduce stress and disturbance for the female, and three days later she laid 6 eggs in the sand-filled box. Eggs measured 6 - 6.5 cm in length, and 3 cm in diameter. The eggs were incubated together in damp vermiculite or perlite (see Table 1), half-buried, at 27-28°C. The incubator allows some incidental room light in, but no special precautions were taken to keep eggs in the dark.

Incubation time varied considerably: the first monitor hatched after 265 days, the last after 316 days. The mean values of the neonates from this clutch were 12.2 cm snout-vent length (SVL), 30 cm in total length (TL), and weighed about 28 g. The babies started feeding seven to ten days after emerging from their eggs. Table 2 shows the incubation-parameters for the clutches 6, 7 and 8, where we tried to study the water-uptake of the eggs under different water-to-substrate ratios.

Different care for juveniles is not required. They are usually kept together in a slightly smaller terrarium than that used for the adults, but with the same design features. Young are fed insects, fish, pieces from guinea pigs (e.g. heart, liver, ribs, legs with skin, and muscles) and occasionally pieces of beef heart, three times per week. At the end of four months, young monitors measure about 20.1 cm SVL and 49.1 cm TL (mean value).

Three years after hatching, the monitors reached a total length of 80 cm. In November 1992 one offspring pair produced a first clutch, a second in November 1993, and a third in September 1994. The first two clutches failed to develop, but the third, which is mentioned above as clutch no. 11, developed and is still (May 1995) incubating.

SUMMARY

Mertens' monitor is a hardy and easy to keep species, when provided with adequate housing, including sufficient water, which allows the lizards to swim and dive. Our two pairs can each routinely and safely be housed together year round.

Mating is at the beginning of the Australian wet season, following a semi-brumation period in June to August. Egg-laying has always occurred three weeks after copulation. Eggs can be successfully incubated in media with very variable ratios of substrate-to-water, ranging from 1:0.25 to 1:5.

Table 1: Breeding data of *Varanus mertensi*

Clutch No.	Copulation	Egg Deposition	Eggs (n)	Incubation Period (days)	Hatch-lings (n)	Mean SVL (cm) x	Range of Variation Sx
1	2 Sept 88	25 Sept 88	6	265-316	6	12.1	0.29
2	17 Oct 89	8 Nov 89	6	285-317	4	11.9	1.27
3	3 Nov 90	3 Nov 90	6	286-304	6	13.1	0.21
4	25 Oct 91	15 Nov 91	7	293-327	7	13.2	0.32
5	-	4 Jan 92	6	258-308	6	12.5	0.21
6	28 Dec 92	20 Jan 93	7	204-294	7	13.1	0.46
7	24 Feb 93	18 Mar 93	8	229-277	8	12.2	0.33
8	29 Mar 94	19 Apr 94	6	193-305	6	12.7	0.54
9	12 Jun 94	6 Jul 94	8	239-306	8	12.4	0.24
10	12 Aug 94	6 Sept 94	8				
11	-	12 Sept 94	6				

Clutch No.	Mean TL (cm) x	Range of Variation Sx	Mean Ratio SVL:TL x	Range of Variation Sx	Mean Weight (g) x	Range of Variation Sx
1	17.8	0.35	1:46	0:03	28.0	1.35
2	17.1	2.47	1:44	0:08	27.1	7.55
3	18.3	0.47	1:40	0:05	33.0	1.01
4	18.6	0.43	1:40	0:05	32.4	0.60
5	18.6	0.47	1:48	0:03	30.8	1.22
6	18.7	0.81	1:43	0:06	32.7	2.15
7	17.4	0.85	1:43	0:06	26.7	1.04
8	18.3	0.99	1:44	0:06	33.6	1.28
9	17.6	0.36	1:42	0:04	27.5	0.70
10						
11						

Table 2: Incubation parameters for clutches 6, 7 and 8

Clutch No.	Substrate	Ratio substrate-water	Incubation Period (days)	Mean egg-weight (g)	Mean weight of hatchlings (g)
8	wiremesh	control	296-305	47.9	33.9
7	vermiculite V4	1:5.0	229-250	38.5	27.0
6	vermiculite V1	1:2.5	283-290	48.6	34.2
6	vermiculite V2	1:1.2	204-207	49.0	29.9
7	vermiculite V3	1:0.6	250-263	38.0	27.2
8	vermiculite V5	1:03	193-223	47.3	32.4
7	perlite P4	1:4.0	274-277	36.9	25.5
6	perlite P1	1:2.1	246-284	49.2	33.3
6	perlite P2	1:1.0	294	48.5	34.7
7	perlite P3	1:0.5	230-235	39.2	27.2
8	perlite P5	1:0.25	244-253	48.6	34.5

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Dr Bernd Schildger, veterinarian at the Frankfurt Zoo, kindly performed endoscopic examinations of the monitors to ascertain sexes. Robert Sprackland made some useful suggestions.

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HERBIVORY IN *EGERNIA HOSMERI* (SQUAMATA: SCINCIDAE)

G.M. Shea
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University of Sydney, NSW, 2006.

INTRODUCTION

Several of the large skinks of the genus *Egernia* remain poorly known ecologically, despite their popularity as captive animals. This lack of knowledge is exacerbated by the rarity of the species in museum collections. One of the least-known of the larger *Egernia* is Hosmer's Skink, *Egernia hosmeri*. Originally described from three specimens from north-east Queensland (Kinghorn, 1955), there have been almost no records of the species from this part of its range since then. Stammer (1976) reported the species from north-west Queensland, where he found it to live in crevices in granite and pegmatite outcrops, in colonies of two to nine animals (which he interpreted as family groups). Stammer also noted that colonies used communal defaecation sites, a feature also reported for other crevice-dwelling *Egernia* (Bredl *in* Banks, 1986; Bustard, 1970a; Hickman, 1960; White, 1976; Wilson & Knowles, 1987). Essentially similar ecological descriptions of *Egernia hosmeri* were provided by Bustard (1970b), Swanson (1976), Cogger (1986), Wilson and Knowles (1987), Horner (1991) and Ehmann (1992), although the latter three publications also record the species sheltering in hollows in dead timber. Panting by heat-stressed individuals was reported by Webb *et. al.* (1972; see also Ehmann, 1992).

Banks (1986) reported on a captive colony at Melbourne Zoo, including activity periods, both seasonal and circadian, behaviour, diet and reproduction.

A brief visit to the Mt Isa district in April 1994, during which a number of *Egernia hosmeri* were observed in rock crevices, gave the opportunity to gather some dietary data on wild populations of this species.

MATERIALS AND METHODS

During handling or while being temporarily held in bags, several lizards defaecated, and a series of twelve scats was collected and preserved in alcohol (Series A). Two additional series (Series B-C) of dry scats were collected from rock outcrops in areas inhabited by *E. hosmeri*. Series B, a mixture of 17 complete and several incomplete scats, was sampled from a large deposit of scats in a sheltered rocky depression in a large outcrop, approximately 1km away from Series A. Series C, consisting of seven complete and several incomplete scats, was a pooled sample taken from several exposed rock ledges and crevices on a hill within 500m of each of Series A and B.

Dry scats were subsequently weighed to the nearest 0.1g, soaked in 70% alcohol for 24hrs and re-weighed after being blotted dry. Scats were individually broken up in Petri dishes and examined under a dissecting microscope.

Dissected scats were lodged in the Australian Museum collection, under the number R147429.

RESULTS

Dry scats were light to dark olive-green, generally with a rough fibrous surface texture. All scats rapidly stained the alcohol green.

Dry and wet weights for entire Series B scats were 0.1-0.6g (= 0.28g, sd = 0.15g) and 0.3-1.2g (= 0.77g, sd = 0.29g) respectively and for entire Series C scats were 0.1-0.5g (= 0.22g, sd = 0.15g) and 0.2-1.2g (= 0.61g, sd = 0.39g).

In all three series, all scats were predominantly composed of fibrous or pubescent plant material and fruiting bodies. In many cases (one from Series A, nine from Series B, two from Series C) the scats contained no identifiably animal material. Several different fruits and seeds were present in different scats. The most common fruit (present in six scats in Series A and seven in Series C) was a rounded smooth septicidal capsule about 6mm in diameter with three carpels, each of which bore a low obtuse median longitudinal ridge externally, and carried several white ovoid seeds. Up to five such fruits were present in a scat. Other fruits included berries and capsules of several species,

and awned grass seeds. The vegetative material was mostly thoroughly chewed and broken up, but appeared to include both leaf and stem material.

When animal material was present, it constituted much less than 0.1g (wet weight) for each scat, with one exception, a scat from Series B in which shed *E. hosmeri* skin predominated. Six shed *E. hosmeri* scales together with a single osteoderm were also seen in one scat from Series A. Other recognisably animal material consisted of insect chitin. Among these were partial elytra and legs of small beetles (Coleoptera, some recognisably weevils, family Curculionidae), heads and abdomens of bugs (Heteroptera), legs of grasshoppers or crickets (Orthoptera) and small insect head capsules, some possibly ants (Hymenoptera, Formicidae), although no scat demonstrably contained the remains of more than three insects. One scat from series A contained the apical segment of a land snail shell.

Scats from all series contained occasional pieces of grit and gravel up to 2mm in diameter.

Large numbers of nematodes were present in the fresh scats from series A.

DISCUSSION

Although Series B and C could not be definitely proven to be *E. hosmeri* scats, they were similar in size, shape and contents to the scats of Series A. Additionally, one scat from Series B contained a number of *E. hosmeri* shed scales. Uric acid pellets incorporated in some of the scats from Series B and C identify them as non-mammalian, while the solid structure of the scats argues against them being of avian origin. Of the reptile species observed in the area, *E. hosmeri* was by far the most conspicuous, and the only one likely to live in the long-term colonies necessary to have produced the deposits from which the scats were sampled. All available evidence therefore argues for *E. hosmeri* having produced the scats in all three series.

While faecal pellets do not allow quantifiable dietary analyses, due to differential digestion and the loss of fully digestible food items (Floyd & Jenssen, 1984; Schoener, 1989), the extreme dominance of plant material in *E. hosmeri* scats suggests that this species is largely herbivorous. In comparison with the scats analysed for an insectivorous pygopod, *Delma impar* (Coulson, 1990), an insectivorous skink, *Eulamprus tenuis* (Rankin, 1973) and a largely herbivorous skink, *Tiliqua rugosa* (Bamford, 1980; see Dubas & Bull, 1991; MacMillen *et. al.*, 1989; Shea, 1989 for diet of this species), the scats of *E. hosmeri* are remarkably insect-poor.

The results of this study are in agreement with reports of a predominantly herbivorous diet in other large *Egernia*, including *E. cunninghami, E. kingii, E. kintorei, E. major* and *E. stokesii*, both in the wild and in captivity (Arena, 1986; Banks, 1986; Barwick, 1965; Brown, 1991; Conran, 1983; O'Loughlin, 1966; Pianka, 1986; J. Read, *pers. comm.*), but do not agree with captive observations. Banks (1986) reported captives feeding largely on live crickets, with plant material only provided once a week, and cited R. Bredl in reporting feeding on grasshoppers that had sheltered in rock crevices. This discrepancy may be due to the lack of opportunity by captives to feed on plant material, or conversely, a lack of opportunity by wild populations to chase moving animal prey from the confines of their rock crevices. Plant material would presumably be more accessible in brief forays from shelter sites. Further study is required to resolve this inconsistency.

Pough (1973) reported a relationship between body mass and diet in lizards, with lizards weighing more than 300g being mostly herbivorous. Among skinks, the smallest herbivorous species had an adult mass of about 100g. Exact values for the mass of *Egernia hosmeri* are unavailable. However, using the relationship between SVL and mass for lizards presented by Pough (1973), and assuming an adult SVL about 140mm (Kinghorn, 1955), *Egernia hosmeri* has a predicted mass of about 100g, close to the lower size limit for herbivorous skinks.

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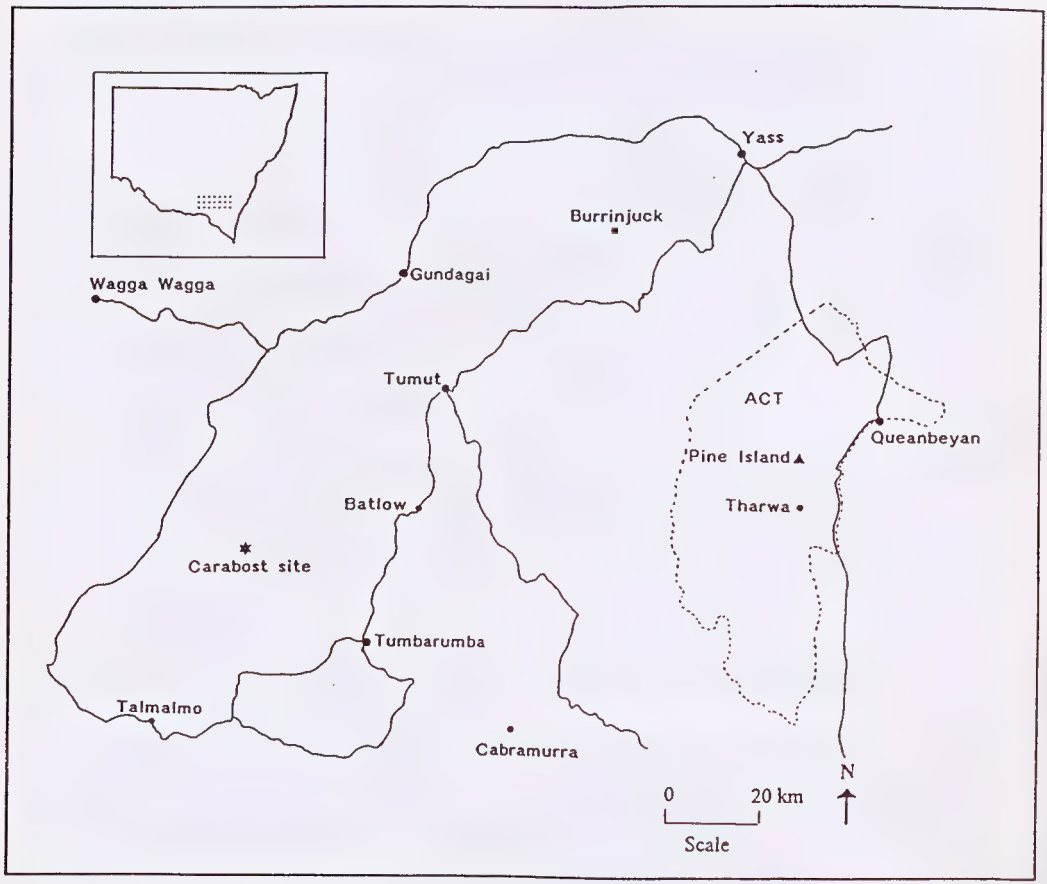
A FURTHER RANGE EXTENSION OF THE BROAD-PALMED FROG *LITORIA LATOPALMATA*

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Rauhala and Osborne (1994) recently extended the known southerly range of the broad-palmed frog (*Litoria latopalmata*) to the Pine Island area of the Murrumbidgee River in the ACT. We report a further range extension for this species with a new record 130 kilometres to the south-west of Pine Island (see Figure 1).

Between October 1994 and April 1995 surveys were undertaken in and around the State Forests of the Tumut and Tumbarumba areas of southern NSW. These surveys encompassed an area in a rough triangle from Burrinjuck in the north, south to Cabramurra and west to around Talmalmo on the Murray River (Figure 1). All the terrestrial vertebrate groups were surveyed during this period using standard methodologies (e.g. Law, 1995; Lemckert, 1995).

Figure 1. Relative position of new distribution record for *Litoria latopalmata*.



On the evening of the 27th February bat surveys were being conducted by three of us (BL, JA and MC) at a stock watering dam adjacent to Carabost Creek Road in Carabost State Forest (35°3930"S X 141°3855"E). During this survey, an unidentified moderate-sized frog (approximately 40mm snout-vent) was observed sitting on the edge of the water. This individual was caught and photographed. Later examination of the photograph by one of us (FL) clearly identified the individual as an adult, female broad-palmed frog (*Litoria latopalmata*) through body shape (that of a ground dwelling hylid) and the size and shape of the head stripe (broad as the tympanum and notched in front of the eye).

The record site appeared to be typical of areas utilised by this species (based on Cogger, 1992 and F. Lemckert, pers. obs.). The dam was approximately 15 metres in radius with little vegetation within it or on the edges and was located in an area of open woodland consisting of Blakleys red gum (*Eucalyptus blakleyi*), yellow box (*E.melliodora*) and apple box (*E.bridgesiana*). The dam showed signs of being recently disturbed by cattle.

Rauhala and Osborne (1994) were uncertain if this species had recently expanded its range into the ACT or simply had not been noticed prior to 1985 due to the inaccessibility of the known breeding sites. It was originally considered that the latter was likely to be the case. However, a substantial survey of the general area by Caughley and Gall (1985) some 15 years earlier failed to locate this species, suggesting it was not present at the time. Furthermore, Will Osborne (pers. comm.) has recently heard this species calling 50 km north of our site at two farm dams near the turn-off to Wagga Wagga from the Hume Highway, an area also covered by Caughley and Gall (1985). These additional records of Will Osborne indicate that the broad-palmed frog is currently widespread through the area. If this was the case at the time of the surveys of Caughley and Gall (1985), they should have located this species. We therefore suggest that it is more likely that the broad-palmed frog has recently been increasing its range and the question arises as to how and why such a recent expansion would have occurred? Perhaps the continued introduction of dams suitable for breeding sites is allowing a slow expansion into previously uninhabitable areas. However, the main expansion of the dam system is likely to have happened immediately after World War II with the returned soldier settlement scheme and it is difficult to see why the frogs would not have invaded this region at that time. No other explanation is yet apparent. Whatever the reason, a frog undertaking a range expansion is an unusual event in a world where many amphibian species appear to be on a serious decline.

We agree with Rauhala and Osborne (1994) that such significant new findings indicate the importance of monitoring programs and, more importantly, that surveys need to be undertaken in "unexplored" areas in order to establish the current range limits of species so that future range expansions and, more importantly, range declines can be detected.

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OBSERVATIONS OF *VARANUS GOULDII* (VARANIDAE) AT MON REPOS BEACH, BUNDABERG

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INTRODUCTION

The Sand Monitor or Goulds Goanna, *Varanus gouldii*, is a species that occurs through most of continental Australia (Cogger, 1992). This paper reports on the breeding and natural history of the *V.gouldii* population at Mon Repos Beach near Bundaberg in Southern Queensland.

STUDY SITE AND METHODS

Detailed observations of the reptiles at the Mon Repos Environmental Park (latitude 24°48S, longitude 152°26E) have been made by the author since December, 1985 as part of the Queensland Department of Environment and Heritage surveys of local fauna.

The Mon Repos Environmental Park (MREP) consists of a 0.2 km wide strip of frontal dune 1.2 km in length. The dunes were cleared of trees prior to the turn of the century and have been a grassland grazed by cattle until the mid 1970s. These grassed dunes have been partly revegetated with a range of native tree species including *Casuarina equitifolia* along the frontal crest of the dune since 1978.

V.gouldii were searched for on foot at different times of the day from October to February each year and captured by hand. Snout-vent length (SVL), tail length (TL) and any distinguishable damage or markings were recorded. The goannas were sexed using blunt ended probes to determine the presence or absence of hemipeni in the base of the tail.

Those individuals lacking extensive characteristic natural injuries were tagged by mutilation marking. The digits were numbered from left to right with units on the forelimbs and tens on the hindlimbs. The assigned digit was marked by removal at the distal joint with no more than two digits ever being marked.

RESULTS AND OBSERVATIONS

There was a period from 1948 to 1985 when *V.gouldii* were not observed on these sand dunes (C.Limpus pers. comm.). From 1985 the numbers of *V.gouldii* at Mon Repos slowly increased to the point where several different sized *V.gouldii* could be seen in a two week observation period.

During December 1986 to January, 1987 three different very small *V.gouldii* were recorded that were presumed to be less than one year old. One of these post hatchlings had a distinctly shortened tail and it evaded capture by escaping down the same burrow (Burrow 1) on each of the three different attempts to secure it. Burrow 1 was beneath a rock pile adjacent to the MREP Research Centre. On the 20th December, 1987, this same *V.gouldii* with the distinctly damaged tail (now presumed to be in its 2nd year) was captured within 20 m of where it had been seen the previous year and marked No. 1: SVL = 36.9 cm, TL = 31.7 cm, sex = female. She was again sighted on the 2nd January, 1988, walking near the MREP Research Centre, approximately 40 m from the first capture site. On the 14th January, 1988, she was recaptured while walking through short grass in the same location: SVL = 36.9 cm, TL = 31.7 cm.

Examination of undated photographs taken during winter of 1988, showed this *V.gouldii* female in courtship (Figure 1) with an approximately 130 cm male (No. 4) adjacent to the first capture site for the female. The courtship took place for about 15 mins with the male biting the female on the neck and displaying to her by intermittently distending his throat ventrally. The male held the female by the neck with his mouth and mounted her. She was pinned beneath the male with the ventral surface downward at the shoulders and the pelvic area rotated laterally to provide the male access for insertion. The male clasped the female in front of her shoulders with his forelimbs. The tail of the male was under that of the females from the right side and he gripped the hindquarters of the female with his left hind limb over her pelvic region to hold the two cloacas together. Throughout

the copulation, the male continued with ventral throat distention even after he released his mouth hold on her neck.

Figure 1. Copulating *Varanus gouldii*.
The smaller lizard with the deformed short tail is female No. 1. The male is on top.



Female (No. 1) was recaptured again on the 4th January, 1989 as she was trying to escape down a burrow (Burrow 2) which was located under trees on the back of the dune and approximately 100m from the first capture site: SVL = 37.4 cm, TL = 33.5 cm. By palpation she was found to be carrying approximately six large ovarian follicles or unshelled oviducal eggs. On the 27th January, 1989, female No. 1 was sighted about 15m from Burrow 2, apparently being stalked by a large *Pseudonaja textilis*. Female No. 1 was again captured on the 8th February, 1989 as it was wandering near the MREP Research Centre adjacent to the second capture site: SVL = 37.4 cm, TL = 33.5 cm. Palpation revealed that she carried no enlarged ovarian follicles or oviducal eggs at this time. She had laid a clutch between these last two captures. This *V.gouldii* has not been seen since.

In summary, female No. 1 was observed nine times over a two year period in an area that was less than 60 m in radius. She was probably born very close to this site, if not within it. During her second year she was mated within this small area and she laid her first clutch during January in or near this same area when she was approximately 3 years old, with SVL = 37.4 cm. *V.gouldii* females at this subtropical study area can reach sexual maturity during their second year and breed at three years old. This is a comparable age for first breeding to that recorded for female *V.olivaceus*, a tropical species from the Philippines that is a similar sized varanid to *V.gouldii* (Auffenberg, 1988). In temperate areas, *V.varius*, another similar sized varanid, was estimated to reach sexual maturity in four years (Carter, 1992).

The male *V.gouldii* (No. 4) that was involved in the courtship was sighted on several occasions the previous summer approximately 1 km north of where he was observed in courtship. During the summer after mating, this male was seen on the 7th January, 1989, hanging onto the wall of the MREP Research Centres fern house. It was subsequently sighted on several other occasions up to 250m from the courtship site. On the 19th January, 1989, a *V.gouldii* of approximately 130 cm (according to track size) took a bait (1080) that had been laid out by the National Park Staff to control the local population of introduced European Foxes, *Vulpes vulpes*. The only goanna of that size that had been seen in the study area was the male No. 4. Neither this *V.gouldii*, nor its tracks, have been seen since.

These varanids when pursued never attempted to climb trees but made ready use of burrows. This is consistent with their behaviour at other locations (Houston, 1978).

The posture that the *V.gouldii* adopted during copulation is similar to that of the Komodo monitor, *V.komodoensis*, with the tails of both parties twisted together and the hind leg holding the cloacas in contact to each others (Auffenberg, 1978). However, the rotation of the pelvic area of the lower lizard and the crossing of the tails at the cloacal region is also seen during ritual fighting by male *V.gouldii* (Cogger, 1992).

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by John E. Gray and Albert Gunther

with an introduction by Glenn M. Shea (University of Sydney)

This book represents the first monograph dealing exclusively with the herpetofauna of Australia and New Zealand. It consists of two separate but related works that share the same set of plates. The first of these, by Gray and Gunther, was issued in two sections (1845, 1875), as part of the scientific results of the voyage of H.M.S. *Erebus* and *Terror*, commanded by Captain Sir James Ross Clark, and sent by the British Admiralty during 1839-1843 to determine the limits of Antarctica and to explore Australia and New Zealand. This was the first comprehensive review of the lizards of Australia and New Zealand and gave the scientific name, synonymy, description, and distribution of each species. Many new species were described for the first time. The second work being reprinted in this volume is Gray's monograph, "The Lizards of Australia and New Zealand in the Collection of the British Museum" (1867), which was also a checklist containing the basic details for each species.

The outstanding feature of this reprint are the 20 lithographic plates, drawn by G.H. Ford, staff artist at the British Museum and one of the best natural history artists of the 19th century. These plates illustrate monitors (4 plates), pygopodids (1), geckos (3), skinks (9), agamids (2), and one of the tuatara, which was then classified as an agamid lizard. These exquisite drawings are among the most detailed and lifelike ever produced on the Australian and New Zealand herpetofaunas. They represent the first published illustrations of many of these species, including the tuatara. Half of the plates illustrate single animals in natural poses, whereas each of the others have as many as 15 figures.

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SEASONAL MOVEMENT IN THE FROG *LITORIA MEIRIANA*

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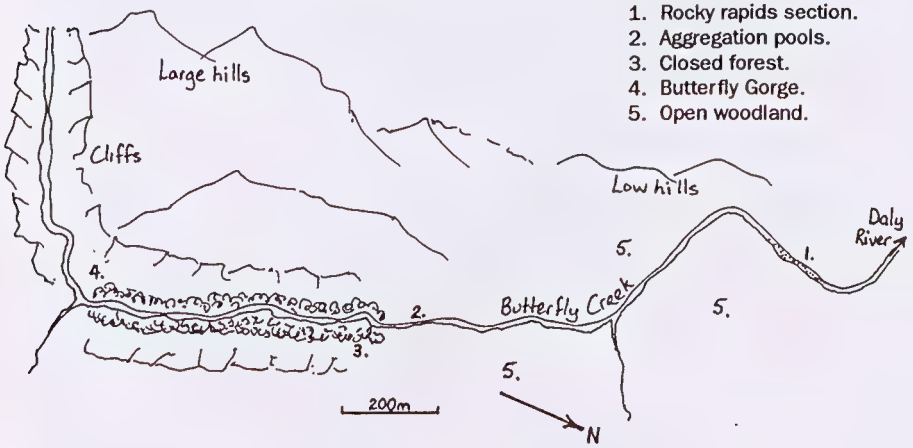
ABSTRACT

Evidence for seasonal movement over at least one kilometre was recorded in the tiny tropical frog *Litoria meiriana* in the Daly River district in the Wet/Dry Tropics of the Northern Territory. This evident movement took place as the dry season progressed and the lower reaches of Butterfly Creek dried out. *Litoria meiriana* is described as an inhabitant of "permanent creeks and waterholes" (Cogger 1992) or "pools upon rock escarpments and outcrops" (Tyler 1992).

SITE DESCRIPTION

Butterfly Creek is located 6km E of the Daly River crossing at 13°44S and 130°41 E. It flows from a narrow steep sided gorge, known locally as Butterfly Gorge. It has a small catchment area and flow is restricted to the period from December or January to April or May. Flow duration varies from year to year and is dependent on both total wet season rainfall and overall wet season duration. During the late wet season of 1992-93 flow was rapid with the creek being 2m - 3 m wide and 0.3m - 0.6m deep. As the dry season took hold into late April and May 1993 stream flow ceased and the creek was reduced to a series of pools. There is a narrow 600m section of gorge that retains some small permanent pools throughout the dry season. These pools are protected by a corridor of dense closed evergreen monsoon forest dominated by the trees *Horsfieldia australis, Syzygium angophoroides* and *Calophyllum sil.* (See Figure 1).

Figure 1 Diagram of the Butterfly Creek site.



OBSERVATIONS

During early April 1993 large numbers of adult size *Litoria meiriana* were observed in daylight hours along a rocky section of Butterfly Creek about 1km downstream from the gorge. A low sandstone hill abuts the creek at this location and the bed and surrounds of the creek are covered in sandstone rocks of varying sizes. Between this location and the gorge are several other rocky sections but much of the intervening creekbed is sandy. At this time stream flow was still rapid but had dropped considerably from that of February and March. The frogs were most abundant in open sunny sections where the creek flowed as rapids through and over rocks. They could be found throughout the stream but appeared to favour rocks that were wetted by surging stream flow.

By May the creek had stopped flowing and large pools remained in the areas of deeper stream bed erosion. Most of these pools between 1 and 2km downstream from the gorge dried out rapidly over a period of a few weeks. The pools within 1km of the gorge dried out much more gradually in more or less a sequence back up the stream over the period from June until September.

As the width of the valley gradually closed in up this gradient the bush changed from open woodland to almost closed canopy woodland to finally closed monsoon forest in the gorge. On successive visits to the creek from June to September the creekline was followed in order to check the drying pools. These visits were made at intervals of around one or two weeks. *Litoria meiriana* congregated around these pools but as one pool dried out the number of frogs around it would decrease and numbers of frogs increased at the next drying pool upstream. Presumably these tiny frogs were moving gradually upstream as the pools dried. By September 3rd. a pool less than 1m in diameter about 100m downstream from the gorge had over 20 *L.meiriana* around it while a 2m diameter pool 20m closer to the gorge had nearly 200 *L.meiriana* around it. Two weeks later the small pool was dry and no frogs could be found despite extensive digging in the still moist leaf litter and turning the labyrinth of rocks present in one corner of the depression. The 2m pool had reduced to only a few cms across and only 2 *L.meiriana* were present although there were still dozens of the *Crinia bilingua* that had been present two weeks earlier. Again extensive digging and rock turning failed to uncover any *L.meiriana*.

L.meiriana were then found in small numbers around the edges of some of the pools that were in deep shade inside the closed monsoon forest. They were difficult to locate in the monsoon forest and seemed to be much more cryptic, hiding in leaf litter. They were unable to sit in the sun as is their normal habit. No *L.meiriana* had been located in the monsoon forest before this date during numerous visits there. On previous visits specific searches had not been made to locate *L.meiriana* though similar searching techniques and efforts were made to locate other species. The numbers of *L.meiriana* that could be located in the monsoon forest never approached anything like the numbers that were located in the open sunny areas further downstream earlier in the year. On the hot steamy night of October 24 1993, during a 2 hour spotlighting visit, around 300-400 frogs of seven different species were seen inside the closed monsoon forest.

In descending order of total numbers seen were *L.wotjulumensis* 60%, *L.tornieri* 20%, *L.coplandi* 10%, *L.nasuta, L.meiriana, Crinia bilingua* and *L.microbelos*. Incredibly on my next visit to the gorge on November 19 not one frog was seen in an hour of spotlighting. In between the 2 visits there had been several episodes of rain totalling around 75mm including 25mm on the afternoon of the 19th. Again no frogs were seen in the closed monsoon forest during the next visit on November 26 though both *L.tornieri* and *L.wotjulumensis* were seen in adjacent open woodland leading up to the gorge.

DISCUSSION

The great increase in numbers of L.meiriana in a progressive sequence at drying pools appears to provide strong evidence for a gradual migration by this species at Butterfly Creek. By following the drying pools upstream refuge is eventually taken in the closed monsoon forest. This refuge appears to be used for only a short term duration the length of which would depend on the onset of the wet season.

The available literature suggests that closed monsoon forest is atypical habitat for *L.meiriana* and none was found there while the creek was flowing. In areas where the only available water bodies are within such closed forests *L.meiriana* may be compelled to move to them during the late dry season. It may be that only a portion of the population takes this course of action. Seemingly suitable areas of temporary refuge such as under moist leaf litter and creekbed stones back out in the open forest section of the creekbed were not used to sit out the end of the dry season and there is nothing to suggest that this species is a burrower in dry times. Perhaps shelter was sought by some of the frogs in other inaccessible refuge sites such as under much larger rocks on the sides of the creekbanks. Certainly the numbers of *L.meiriana* found in the closed monsoon forest were far below those of the numbers seen out in the open creek bed. However during the fairly short period of their stay in the gorge potential predator numbers, of the other larger species of frogs, was extremely high and may account for their more cryptic behaviour and thus a much greater than normal difficulty in locating them. None of the other species seen in the gorge on October 24

were frogs that are noted inhabitants of closed monsoon vine forests but most of the larger frogs would no doubt happily eat a *L.meiriana*.

Following the onset of rains the disappearance from the closed monsoon forest of all species seen on October 24 appears to suggest that some individuals of all these species take refuge within that forest during the dry season. Once the rains begin they appear to move back out into their normal habitat of open woodland surrounding rocky and/or sandy creek. This sort of habitat can be found in all directions around the gorge and specimens of *L.wotjulumensis* and *L.tornieri* were seen in open woodland during the walk up to the closed forest on November 26.

Interestingly none of the common species that were expected to be seen in the closed monsoon forest was found there. These species were *L.caerulea, L.rothi* and *L.rubella* all of which are very common in wetter forest around the banks of the Daly River adjacent to the authors former residence in Nauiyu Nambiyu.

Nor were any species of burrowing frog recorded in the closed forest. Presumably they have no need to seek more mesic refuges and simply burrow adjacent to their breeding and feeding areas. *Cyclorana australis* and *Limnodynastes ornatus* are abundant, and *Cyclorana longipes* common, in open forest around Butterfly Creek about 1.5km downstream from the gorge.

Small pockets of closed monsoon forest such as this may play an important role in the dynamics of the frog population in the surrounding dry woodland. *L.meiriana* may depend on this refuge during the late dry season in this locality. It is then able to repopulate the more favourable portions of habitat further downstream during the wet season. These areas are certainly not permanent water and specimens of *L.meiriana* were recorded over 2km from the permanent pools in the gorge. These specimens were seen next to another very small patch of monsoon forest but whether frogs from this area migrated all the way up the creek or stayed put is unknown. Some individuals of the other species recorded in the gorge may acquire some advantage by seeking refuge in the gorge. Certainly these other species do not need closed monsoon forest in order to survive for they are found extensively over the Top End in areas where such mesic pockets do not exist. However the existence of such a refuge may allow the overall population of the area to be greater than that of an area where no such refuge exists. Pockets of closed monsoon forest such as at Butterfly Creek appear to be of very high conservation value.

It will be interesting to see what sort of impact *Bufo marinus* has on the frog population when the cane toad finally arrives in this area.

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REPRODUCTIVE OUTPUT IN TWO SPECIES OF SMALL ELAPID SNAKES

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The front-fanged venomous snakes of Australia constitute a remarkable adaptive radiation of vertebrates: elapid species have evolved to occupy a wide variety of ecological niches in this country, and exhibit a correspondingly high diversity in body sizes, shapes and colours (e.g. McDowell 1985). Nonetheless, detailed information remains unavailable for many species. The most extensive information (and for many species, the only quantitative information) comes from examination and dissection of large numbers of preserved specimens in museums (see Appendix in Shine 1991). Although we can learn a great deal from this technique, there are many things that cannot be measured on preserved animals. For example, it is difficult to determine sizes at birth, dates of oviposition, hatching or birth, or reproductive output relative to the mother's body size. There is much current interest in the evolution of life-history "strategies" in reptiles, but information on Relative Clutch Mass (a measure of litter mass relative to the mother's mass) is available for relatively few snake species (Seigel et al, 1986). During fieldwork in early summer 1994, we captured gravid specimens of two small elapid species. Because there are few detailed records of litter sizes, offspring sizes or Relative Clutch Mass for these common species, we kept these females in captivity until they gave birth. This paper describes the patterns of reproductive output that we recorded.

The two species are the Swamp Snake (*Hemiaspis signata*) and the White-lipped Snake (*Drysdalia coronoides*). The comparison between these two species is of particular interest, because they are similar in mean adult body sizes and in general appearance. Although previous phylogenetic work has not clearly resolved the relationships between these taxa, current work by one of us (JS Keogh) shows that the hemipenes of these two genera are very similar to each other, and quite different from those of any other Australian elapid snakes. Thus, it seems likely that *Hemiaspis* and *Drysdalia* form a natural (monophyletic) evolutionary lineage. Also, previous ecological work has shown a broad similarity between these two genera in diets (both feed on lizards and frogs) and reproductive cycles (Shine 1981, 1987).

The three White-lipped Snakes were collected on 5 December in the Brindabella Ranges, 40 km west of Canberra. The two Swamp Snakes were caught on 14 December near the Allyn River adjacent to Chichester State Forest in New South Wales. All of the females were maintained at the University of Sydney under natural day length. *Hemiaspis* females were housed in clear plastic boxes measuring 22 x 22 x 8 cm and *Drysdalia* females were housed in similar boxes measuring 22 x 13 x 8 cm. Topsoil was used as a substrate and one-half of each cage was heated with an underfloor heating coil so that the females could thermoregulate freely. Cages were checked daily and the females were weighed approximately every two weeks. As soon as we saw that birth had occurred, we reweighed the female and weighed, measured and sexed her offspring. The females and babies were then preserved and deposited in the Australian Museum (registration numbers R147370 - 147399).

Table 1 provides the data on these females and their offspring. All gave birth over the period 8 - 28 February, in keeping with the reproductive timing previously inferred for these species (Shine 1981, 1987). Indeed, most viviparous temperate-zone Australian snakes seem to produce their offspring at about this time (Shine 1991). Perhaps the most impressive aspect was the high reproductive output relative to the mother's size in the White-lipped Snakes: Relative Clutch $Mass_1$ (definitions in Table 1) of this species averaged 1.02, indicating that the total mass of the litter (i.e., including fluids, membranes, etc. as well as the mass of the young) weighed as much as the female did herself after giving birth (Table 1). RCM_1 was lower in the Swamp Snakes (mean = 0.42), although the small sample sizes mean that this difference between the species did not attain statistical significance (unpaired $t = 2.16$, 3 df, $P = 0.12$). RCM_2 was considerably lower than RCM_1

(Table 1), indicating that much of the mass lost by the female at birth consisted of fluids, membranes, etc., rather than simply the mass of the offspring.

Table 1. Reproductive output in two species of small viviparous elapid snakes.
SVL = snout-vent length; female mass before and after birth is shown;
RCM_1 = Relative Clutch $Mass_1$ (maternal mass loss divided by maternal mass after giving birth);
RCM_2 = Relative Clutch $Mass_2$ (litter mass divided by maternal mass after giving birth).
Note that our RCM_2 corresponds to Greer's (1989) definition of RCM(1).

Female #	SVL (mm)	Female mass (g) before	Female mass (g) after	Litter Size	Litter Mass (g)	RCM_1	RCM_2	Offspring Mass (g)	SVL (mm)	Sex
Drysdalia coronoides (White-lipped Snake)										
1	291	18.60	10.90	5	5.91	0.71	0.54	1.07	123	female
	•	ù	ù			ù		1.16	121	male
	•	ù	ù			ù		1.21	116	male
	•	•	•			•		1.23	124	male
	•	•	•			•		1.24	122	male
2	273	13.66	6.03	5	3.84	1.26	0.64	0.72	96	male
	•	•	•			•		0.75	89	male
	•	•	•			•		0.76	93	female
	•	•	•			•		0.78	96	male
	•	•	•			•		0.83	93	female
3	295	13.67	6.59	6	4.61	1.07	0.70	0.68	91	female
	•	•	•			•		0.71	95	male
	•	•	•			•		0.77	98	male
	•	•	•			•		0.80	102	female
	•	•	•			•		0.80	96	male
	•	•	•			•		0.85	101	male
Hemiaspis signata (Swamp Snake)										
1	365	25.90	15.64	5	7.08	0.66	0.45	1.21	128	female
	•	ù	ù			ù		1.40	138	male
	•	ù	ù			ù		1.44	137	male
	•	•	•			•		1.47	135	female
	•	•	•			•		1.56	143	female
2	413	32.80	27.85	4	4.91	0.18	0.18	1.12	129	s'born
	•	•	•			•		1.19	127	s'born
	•	•	•			•		1.24	131	male
	•	•	•			•		1.36	133	male

In most respects, the two species were quite similar. Litter sizes ranged from 5 to 6 in the White-lipped Snakes, and from 4 to 5 in the Swamp Snakes (unpaired $t = 1.46$, 3 df, $P = 0.24$). Offspring were larger at birth in Swamp Snakes (mean = 1.33 g, 133 mm SVL) than in White-lipped Snakes (0.90 g, 103.5 mm), but this difference between the two species was not significant once the variation among females within species was taken into account (two-factor nested analysis of variance with species, and female identification number nested within species, as the factors: species difference $F_{1,20} = 4.42$, $P = 0.13$ for mass, $F_{1,20} = 6.06$, $P = 0.09$ for SVL). Indeed, this variation among females within a species was quite marked: offspring from two of the White-lipped litters averaged 0.77 g (93 to 97 mm), whereas the offspring from the other litter were much larger (1.18 g, 121 mm). Average offspring sizes were more similar in the two Swamp Snake litters (1.4 and 1.2 g; 136 and 130 mm).

Two of the newborn Swamp Snakes were stillborn and could not be sexed with confidence. Of the remainder, males outnumbered females among the captive-born offspring of both species (4 of 7 Swamp Snakes; 11 of 16 White-lipped Snakes). However, this bias was not statistically significant in either case (chi-square test against a null hypothesis of 50% male: for Swamp Snakes, χ^2 = 0.14, 1 df, P 0.50; for White-lipped Snakes, χ^2= 2.25, 1 df, P 0.20). Sons and daughters did not differ significantly in body sizes at birth in either species (White-lipped Snakes: $F_{1,10}$ = 2.61, P = 0.14; Swamp Snakes, $F_{1,4}$ = 0.003, P = 0.96).

Our data are broadly consistent with earlier reports. The largest data sets on these species come from Shine's (1981, 1987) examination of preserved specimens in museums, and from his fieldwork on a population of *H.signata* in the New England highlands, near Armidale (Shine 1977a-c, 1978). Shine (1981) found that seven NSW *D.coronoides* had a mean clutch size of 5, their neonates averaged 98 mm at birth, and their average RCM_1 was 0.49. For *Hemiaspis signata*, Shine (1987) found that NSW females had a mean clutch size of 6.4 and two captive females gave birth to young averaging 125 mm (1.33 g) and 127 mm (1.33 g), respectively.

Although museum specimens are important sources of otherwise hard-to-obtain biological data, observations and measurements of live animals can give us information that we simply cannot get from the museum specimens (e.g., on characteristics such as RCM). There is an important role here for people who have the opportunity and the interest in these animals, to record information on traits of this kind (for examples see Bedford, 1992; Bush, 1992). We believe that it is useful to present the raw data (as in our Table) rather than just summaries or averages, because there are a number of different ways in which these raw data can be used and analysed. For example, there are several different ways in which to calculate RCM. Because there is relatively little published information on reproductive output in live Australian snakes, keeping and publishing accurate reproductive data on captive snakes (including mass of the female as well as her offspring) can provide a base for subsequent comparisons both within and among species.

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NEW PREY RECORDS AND RELATIONSHIPS FOR THE TIGER SNAKE *NOTECHIS SCUTATUS* (SERPENTES: ELAPIDAE) IN TASMANIA

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RECORD OF OPHIOPHAGY

Ophiophagy and/or cannibalism has been recorded for many Australian elapid genera e.g. *Austrelaps* (Shine, 1987a; Fearn, 1994), *Pseudechis* (Sutherland, 1983; Ehmann, 1992; Daly, 1992; Torr, 1993), *Pseudonaja* (Shine, 1991; Ehmann, 1992), *Crytophis* (Shine, 1984), *Rhinoplocephalus* (Ehmann, 1992). This is not unexpected as most Australian elapids (particularly the larger species) are relatively unselective, searching foragers and predate upon a wide range of vertebrates, of suitable size, whenever they are encountered.

Occasional cannibalism has been previously recorded in several populations of tiger snakes *Notechis scutatus* (Worrell, 1970; Shine, 1987b; Schwaner, pers. comm.). In a previous work (Fearn, 1993), after examining gut and faecal material from a large number of individuals from all parts of Tasmania, discovered little evidence of adult *N.scutatus* predation on reptiles and no evidence of ophiophagy and/or cannibalism.

On the 12/11/93 a female *N.scutatus* (SVL 815 mm, WT 185 grams) was examined as a road killed specimen at Liffey in the north of the state. Stomach contents consisted of two neonate male *N.scutatus* (SVL 181 mm, WT 3 grams).

Tasmanian *N.scutatus* are searching foragers, unselective in respect to prey type or size (Fearn, 1993) and ophiophagy may occur more commonly than has been previously recorded, particularly in respect to more agile subadults and small adults preying on neonates and juveniles.

There is no evidence to suggest that *N.scutatus* shares the highly ophiophagus/cannibalistic habits of *Austrelaps superbus* (Shine, 1987a; Fearn, 1994), *Pseudechis porphyriacus* (Sutherland, 1983; Ehmann, 1992; Torr, 1993), and *P.australis* (Sutherland, 1983; Gow, 1989; Ehmann, 1992) where large adult snakes are overpowered and predated upon.

NEW MAMMAL RECORD

On the 10/11/94 a female *N.scutatus* (SVL 920 mm, WT 290 g) was examined as a road killed specimen at Liffey in the north of the state. Stomach contents consisted of an adult and juvenile little pygmy possum *Cercartetus lepidus*. *C.lepidus* is common and widespread in eucalypt forests and woodland in the eastern half of Tasmania. Green (1979) lists *N.scutatus* as a probable predator of this small marsupial (adults average 6-9 grams) and states 'Nests and sleeping places of *C.lepidus* are usually close to the ground and often appear to be of a temporary nature. Sites from which it has been collected are beneath overturned turf on ploughed ground, inside decayed logs and stumps, in a small hole in a green tree, amongst the dead needles of a she oak *Casuarina sp.* which had accumulated in twigs about two metres above the ground, in an old nest of a New Holland honeyeater *Phylidonyris novaehollandiae* situated about one metre from the ground in dense tea tree scrub, in wall cavities of buildings, in a canvas shower bucket hanging in an outbuilding and amongst old clothes in a shed.' All such nest sites and retreats are well within the foraging range of *N.scutatus* (Fearn, 1993).

DISCUSSION

Tasmanian *N.scutatus* are opportunistic searching foragers, unselective in respect to prey type or size. In a previous work (Fearn, 1993) prey records were presented from a large number of individual *N.scutatus* from all over Tasmania. Endothermic prey (mammals, birds) predominated *N.scutatus* prey items in typical forest and mosaic forest/pasture and cropping habitat. Dredge (1981) discovered anuran prey to comprise the bulk of Tasmanian *N.scutatus* diets in particular populations

concentred around the perimeters of shallow highland lakes and lagoons with large frog populations. Fearn (1993) explains the predominance of ingested prey species in particular habitats as a function of individual prey species abundance with foraging snakes encountering abundant prey species more often than less abundant species. Shine (1977c) explains dietary variations in the same way for six species of elapids studied in a highlands region of eastern Australia.

Percentages of endotherms in Australian elapid diets are generally very low (Shine, 1977c; 1991). Shine (1991) lists 74 species of Australian elapids for which ecology and prey relationships are reasonably well known. Of these, only five species (*Oxyuranus microlepidotus* 100%, *O.scutellatus* 95%, *Pseudechis colletti* 75%, *Pseudonaja nuchalis* 90%, *P.ingrami* 100%) consume similar quantities of endotherms as Tasmanian *N.scutatus*. Shine (1977c, 1991) states that small mammal densities are low over much of Australia and so they do not figure prominently in elapid diets resulting in more readily available reptiles and anurans comprising the bulk of ingested prey types. However, in Tasmania mammals of ingestible size are widespread and common to abundant in much of *N.scutatus* habitat. This situation is possibly due to substantially less natural habitat destruction than other Australian states, climatic factors, diverse habitats in a relatively small geographical area, and the absence of introduced predators such as foxes. Tasmanian lowland copperheads *Austrelaps superbus* also appear to consume more mammals than mainland populations (Fearn, 1994). Table 1 (compiled from Green, 1993) lists mammal species in Tasmania that are readily available and of ingestible size to foraging *N.scutatus*. Some of these species (such as the long tailed mouse *Pseudomys higginsi*) are confined to particular regions of the state but are common in those regions and undoubtedly figure in local *N.scutatus* diets. It is unlikely but not inconceivable that other mammals are occasionally captured by foraging *N.scutatus* such as juvenile ring tailed possums *Pseudocheirus peregrinus* whose nests are often constructed in understorey bushes and shrubs close to the ground. However adult female *P.peregrinus* will savagely defend their nests from predators (pers. obs.). The long-nosed potoroo *Potorous tridactylus* and the Tasmanian bettong *Bettongia gaimardi* are not likely to be commonly predated upon by *N.scutatus* but are included in Table 1 on the basis of an anecdotal account by Meredith (1852) who states upon dissecting a large *N.scutatus* that it contained 'a nearly full grown kangaroo rat, ten inches in length with proportionate girth.' Both *P.tridactylus* and *B.gaimardi* are colloquially known as kangaroo rats in Tasmania.

Shine (1977c; 1991) records that birds are very rarely consumed by Australian elapids including mainland *N.scutatus*. The high percentage of birds (nestlings, fledglings) in Tasmanian *N.scutatus* diets (Fearn, 1988; 1993) appears to be due to high passerine densities rather than greater species diversity.

Reptiles are rarely consumed by adult *N.scutatus* across their range (Shine, 1977c; 1987; 1991; Fearn, 1993). Various species of diurnal surface active skinks, mainly *Niveoscincus metallica* and *N.pretiosa* are abundant in *N.scutatus* habitat within Tasmania. While neonate and juvenile *N.scutatus* commonly prey on skinks (presumably because of greater agility), experiments by Dredge (1981) demonstrated that captive adults were generally incapable of catching them.

The bulk of *N.scutatus* prey items are defenceless and incapable of escape, such as nestling birds, or are nocturnal species trapped in their diurnal retreats by foraging snakes (Dredge, 1981; Fearn, 1988, 1993). Adult *N.scutatus* are therefore not adapted to pursuing active prey over open ground.

It is significant that the only known population of *N.scutatus* that subsists predominantly on a diet of skinks is a 'dwarf ' population occurring on Roxby Island off the Eyre Peninsula, South Australia. Schwaner (1985) records mean SVLs of just under 800mm and weights of just under 200 grams for this population and states 'This could have evolved by selection of individuals that matured at small body sizes on islands where prey types were smaller and less easily acquired. Such conditions apparently have existed on Roxby Island since its isolation.' Adult *N.scutatus* in Tasmania would be both functionally and energetically disadvantaged pursuing skinks of around 5 grams in weight.

Tasmanian *N.scutatus* are inaccurate and clumsy predators of rodents on open ground. Dredge (1981) discovered that adult Tasmanian *N.scutatus* failed to initiate successful strikes on laboratory mice at distances of 5cm or more from the prey in open enclosures, with the head of the snake generally passing over the dorsal surface of the mouse.

Table 1. Tasmanian mammals readily available as prey for foraging Tasmanian *N.scutatus*

SPECIES	DISTRIBUTION AND ABUNDANCE	PREVIOUSLY RECORDED PREY
Native		
Dusky Antechinus *Antechinus swainsonii*	Poorly known. Forest habitats.	-
Swamp Antechinus *A.minimus*	Poorly known. Sedgeland and swampy drainage systems.	-
White Footed Dunnart *Sminthopsis leucopus*	Widespread from coastal sand dunes to high altitude forest.	-
Southern Brown Bandicoot *Isoodon obesulus*	Widespread, scrub/forest habitats and adjoining cleared land.	+
Eastern Barred Bandicoot *Perameles gunnii*	Widespread. Grasslands and pasture often bordered by scrub and forest.	+
Little Pygmy Possum *Cercartetus lepidus*	Widespread. Forest and heathland in central and eastern regions.	+
Eastern Pygmy Possum *Cercartetus nanus*	Widespread. Mainly wetter western half of island.	-
Long Nosed Potoroo *Potorous tridactylus*	Widespread. Mainly forest habitats.	+
Tasmanian Bettong *Bettongia gaimardi*	Widespread. Open forests and grassy woodlands in eastern half of island.	+
Water Rat *Hydromys chrysogaster*	Widespread. Waterways from highlands to the sea.	-
Long Tailed Mouse *Pseudomys higginsi*	Endemic. Beech rainforest and adjoining wet sclerophyll forest in western Tasmania.	-
New Holland Mouse *Pseudomys novaehollandiae*	Patchy, mainly coastal distribution.	+
Broad-Toothed Rat *Mastacomys fuscus*	Wet sedgeland and heathland. Central western and southern parts of island.	-
Swamp Rat *Rattus lutreolus*	Widespread. Most habitats.	+
Introduced		
House Mouse *Mus musculus*	Widespread. Abundant over much of state.	+
Black Rat *Rattus rattus*	Widespread. Closely associated with areas of human disturbance.	+
Brown Rat *Rattus norvegicus*	Closely associated with human populations, mainly coastal towns and cities.	-
Rabbit *Oryctolagus cuniculus*	Widespread in pastoral habitats.	+
Brown Hare *Lepus capensis*	Widespread in pastoral habitats.	-
Ferret *Mustella furo*	No established wild populations but individuals commonly abandoned in rabbit warrens by rabbit hunters.	-

A remarkable encounter between an adult female black rat (*Rattus rattus*) of approximately 150 grams and a Tasmanian *N.scutatus* of approximately 1200mm (total length) was recorded at Liffey in January 1981, and amply demonstrates how *N.scutatus* is not equipped to deal with active and potentially aggressive prey in open situations.

One of the authors (CPS) attention was drawn to a disturbance beside a pile of lumber. A highly agitated black rat was observed actively attacking an adult tiger snake. Approximately 600mm of the anterior of the snake was exposed from a cavity beneath the pile. The snake was engaged in typical *N.scutatus* threat display and was repeatedly striking at the rat. The rat, however, remained just out of striking range, and when the snake had reached full extension in the strike, rushed in and delivered a bite to the snakes neck several centimetres behind the head. Although it had every opportunity to flee, the rat was intent on delivering bites to the snakes neck region which it did so every time the snake moved. Throughout the four minute observation the rat was standing erect on its hind legs and weaving rapidly from side to side in a highly agitated state with its eyes clearly bulging. Observations ceased when the snake retreated back under the lumber stack with the rat in pursuit. This interaction was recorded on a warm summers day and the rapid movements and tongue flicking of the tiger snake indicated a body temperature at or near preferred foraging optima of approximately 28°C (Dredge, 1981).

As a postscript to this encounter, the following summer the lumber pile was dismantled and a well decomposed *N.scutatus* of similar dimensions to the above specimen was discovered in a shallow depression beneath the pile. Also present was an old abandoned *R.rattus* nest. While there is no proof that the same *N.scutatus* was involved it is possible that in a confined space offering little opportunity of manoeuvrability for the snake the rat may have been able to deliver a fatal bite or bites to the snakes head or vertebral column in the neck region. The extreme reaction of the rat may have been initiated by the presence of a nest containing young.

In a previous work (Fearn, 1993) rodent bite scars were found to be common on adult *N.scutatus*, particularly in rural habitats. On several occasions large *N.scutatus* were captured with fresh wounds, often involving skin loss. Palpation revealed recently ingested *R.rattus*. Schwaner (pers. comm.) has made similar observations on Chappell Island.

On several occasions both authors have discovered near dead adult *N.scutatus* with extensive, fly-blown animal bite wounds present in the forebody region. *Rattus rattus* grows to unusually large sizes in mosaic forest/pasture habitats in northern Tasmania with some males weighing as much as 500 grams (pers. obs.). *Rattus rattus* is a recent addition to the mammal fauna of Tasmania and such specimens would be formidable opponents to foraging *N.scutatus*.

Notechis scutatus generally hold onto prey once seized and wait for it to succumb to the effects of envenomation before ingestion (Dredge, 1981; pers. obs.). Foraging *N.scutatus* scenting *R.rattus* in the darkness of a burrow or retreat could conceivably be seriously injured after seizing a large *R.rattus* before the effects of envenomation took place.

The only two Australian elapids adapted to routine predation on large, potentially aggressive rodents (the taipans *Oxyuranus scutellatus* and *O.microlepidotus*) avoid such risks by having highly toxic, fast-acting venom and a 'snap and release' biting action giving the prey little opportunity for retaliation (Shine and Covacevich, 1983; Covacevich, 1987).

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DIGESTIVE PROPERTIES OF SNAKE VENOMS

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ABSTRACT

Neonate mice cadavers were injected with snake venoms and subsequently incubated at controlled temperatures for fourteen days. Decay rates were determined by the exudate quantities, measured at two day intervals. The decay rates differed significantly for different snake venoms. Some snake venoms also appeared to possess antibacterial properties.

INTRODUCTION

More than ten components of snake venoms are proteins exhibiting enzymatic properties (Yang, 1974). It has also been postulated that a number of venoms in different venomous animal species originated from salivary enzymes (Wells, 1978). Tu *et al.* (1964, 1965) showed the presence of trypsin-like and other enzymatic activity in snake venoms. These proteolytic enzymes, although in their activity similar to other known digestive enzymes, are not blocked by pancreatic enzyme inhibitors (Tu *et al.*, 1966), while Mebs and Langelueddeke (1992) reported the presence of potent myotoxins in European vipers. This experimental series is designed to investigate the digestive properties of six Australian snake venoms and one non-Australian snake venom. Stiles *et al.* (1991) reported that *Notechis scutatus* and *Pseudechis australis* venoms have antibacterial activity, while Thomas and Pugh (1979) showed that *Crotalus atrox* venom aids digestion.

MATERIALS AND METHODS

The venoms of *Acanthophis antarcticus, Acanthophis praelongus, Notechis scutatus, Oxyuranus scutellatus, Pseudechis australis, Pseudechis porphyriacus* (supplied by Venom Supplies, PO Box 547, Tanunda 5253, South Australia) and *Vipera lebitina* (supplied by I.F.P., Melbourne, Victoria) were used. All the above Australian snake venoms were applied at double the mean lethal dose (MLD), while for *V.lebitina* venom, 2 and 4 MLDs were used.

Dead neonate mice (3-4 days) ranging in weight from 2.9 to 5.8 g (3.8 g mean) were injected with 2 MLD or, in the case of *V.lebitina*, 2 and 4 MLD were injected. All groups contained a minimum of six animals. The venom was dissolved in physiological saline (0.9%). The injected volume of the saline venom mixture was 0.01 ml per 1 gm of tissue. The neonate mice were injected in the peritoneal cavity. Controls were injected in the same position with the same quantities of pure saline.

The neonate mice cadavers, immediately after the venom injections, were incubated in diluted hydrochloric acid (HCl, pH2.5) for 4 hours in order to investigate whether the expected enzyme activity survived simulated gastric acidity (Davenport, 1966; Glass, 1968).

The neonate mice cadavers were put in 10 ml McCartney bottles fitted with rubber septa. The septa were punctured to avoid gas pressure build-up. All bottles were then placed in a temperature controlled cabinet (18°C ± 10%).

The fluid accumulating, as a result of the decaying animal, was withdrawn with a syringe on days 4, 6, 8, 10, 12 and 14. The quantity collected from each bottle was measured by weighing. This method is loosely based on a method described by Meier *et al.* (1990). The decay fluid values obtained were subsequently extrapolated to a 10 gm neonate mouse weight equivalent in order to be able to compare the decay fluid volumes resulting from differing weights of neonate mice cadavers.

RESULTS

The extrapolated values for the decay exudate removed from bottles containing the neonate mice cadavers on days 4, 6, 8, 10, 12 and 14 are presented in Table 1 and graphically demonstrated in Figures 1 to 7.

Table 1. Decaying Effect of Seven Snake Venoms on Dead Neonate Mice
(grammes of exudate per grammes of neonate mice cadavers)

Day	Controls	A.a. 2 MLD	A.p. 2 MLD	N.s. 2 MLD
4	0.31 ± 0.23	0.36 ± 0.19	0.27 ± 0.25	0.17 ± 0.13
6	0.69 ± 0.19	0.32 ± 0.10	0.34 ± 0.32	0.25 ± 0.27
8	0.55 ± 0.22	0.30 ± 0.16	0.39 ± 0.32	0.26 ± 0.10
10	0.40 ± 0.15	0.33 ± 0.10	0.31 ± 0.13	0.62 ± 0.25
12	0.22 ± 0.09	0.34 ± 0.18	0.31 ± 0.19	0.46 ± 0.17
14	0.08 ± 0.07	0.29 ± 0.08	0.28 ± 0.07	0.38 ± 0.17

Day	O.s. 2 MLD	P.a. 2 MLD	P.p. 2 MLD	V.l. 2 MLD	V.l. 4 MLD
4	0.16 ± 0.04	0.68 ± 0.34	0.46 ± 0.15	0.18 ± 0.14	0.09 ± 0.04
6	0.48 ± 0.11	0.48 ± 0.29	0.56 ± 0.30	0.42 ± 0.4	0.13 ± 0.07
8	0.47 ± 0.24	0.55 ± 0.37	0.54 ± 0.40	0.24 ± 0.08	0.21 ± 0.10
10	0.54 ± 0.25	0.37 ± 0.16	0.22 ± 0.08	0.48 ± 0.14	0.19 ± 0.12
12	0.39 ± 0.05	0.39 ± 0.16	0.25 ± 0.12	0.37 ± 0.11	0.27 ± 0.12
14	0.27 ± 0.11	0.23 ± 0.14	0.15 ± 0.07	0.26 ± 0.14	0.44 ± 0.26

The results for *A.antarcticus* (Fig. 1) and *A.praelongus* (Fig. 2) showed a depression of decay activity after day 4, which subsequently remained at the same level until day 14.

The decay rate of *N.scutatus* was initially depressed, but then peaked on day 10, four days after the controls peaked (Fig. 3).

O.scutellatus venom also caused a delay in decay onset and shifted by approximately two to four days (Fig. 4).

The peak decay rate for *P.australis* preceded the maximum control decay rate by two days and then continued similarly (Fig. 5).

The decay rate of *P.porphyriacus* started faster, but then showed no significant difference to the control decay rate (Fig. 6).

In the case of *V.lebitina* the decay in dead mice injected with 2 MLD of the venom was delayed and depressed when compared with control values. Dead mice injected with 4 MLD venom exhibited an even slower decay rate, which began to peak on day 14 (Fig. 7). Due to high standard deviation (SD) values, only results of day 6 were significantly different (at 0.5 level). All decay rate values and their SD are shown in Table 1.

Summarising the results it can be seen that five snake venoms delay or depress the decay rate at 18°C (10%) (*A.antarcticus, A.praelongus, N.scutatus, O.scutellatus* and *V.lebitina*). Two species advance the decay onset (*P.australis* and *P.porphyriacus*). It can also be seen that the *V.lebitina* venom double dose has a markedly greater effect on decay rate suppression. For the sake of simplification the decay rate depressing venoms are called type I and the decay rate advancing venoms type II.

DISCUSSION

It is well documented that snakes are only able to digest their prey within a certain temperature range (Sutherland, 1983). As their body temperature is dependent on the ambient temperature, the temperature optimal for digestion varies daily. It certainly changes seasonally. When the temperature drops below critical levels, digestive enzyme activity ceases and fermentation by bacteria within the prey's viscera can putrefy the prey's cadaver, which may lead to the snake's death (Cogger, 1987).

It therefore makes sense that snake venoms should contain digestive enzymes allowing digestion from within the prey's cadaver, while stomach enzymes begin to dissolve the swallowed animal and visceral digestion continues the process (Cogger, 1987). It would also be beneficial for the snake's survival, if the venom contained anti-bacterial factors, which inhibited activity of psychrophilic bacteria (predominantly *Aeromonads, E.coli* and *Pseudomonads*). This would help to stop or slow down bacterially mediated decay or fermentation at low temperatures.

The observed decay rate suppression by the type I venoms could be due to bacteriocidal/-static activity or due to a digestive enzyme 'switching off' factor at approximately 18°C. Or a combination of both factors could be involved.

Type II venoms possibly accelerate the decay rate at 18°C due to the digestive factors being 'switched on' at this relatively low temperature. This could be due to the species concerned having a greater temperature tolerance.

In mammalian stomachs enzymes are 'turned off' by rising pH values in order to prevent autolysis and 'switched on' when pH values drop (Glass, 1968). It could be possible that snake venoms contain a temperature activated digestive enzyme 'switching' component. The discovery and the purification of such a temperature based digestive enzyme 'switching' factor would be of importance in processes where fermentation or preservation is used.

CONCLUSION

Two main future research directions become obvious. Screening for and the isolation of a possible anti-bacterial component in snake venoms should be instigated. The elucidation of the apparent presence of potent digestive enzyme inhibitors, which are temperature dependent, would be of importance in gastro-intestinal research.

Fig. 1 Decay rate of dead neonate mice injected i.p. with 2 MLD of *A.anarcticus* venom (— • —) and controls (———)

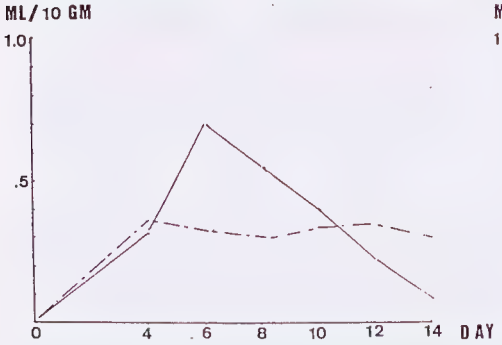


Fig. 2 Decay rate of dead neonate mice injected i.p. with 2 MLD of *A.praelongus* venom (— • —) and controls (———)

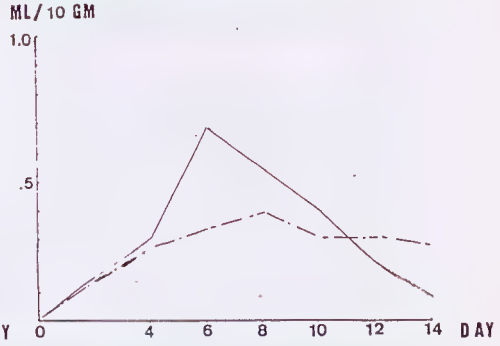


Fig. 3 Decay rate of dead neonate mice injected i.p. with 2 MLD of *N.scutatus* venom (— • —) and controls (———)

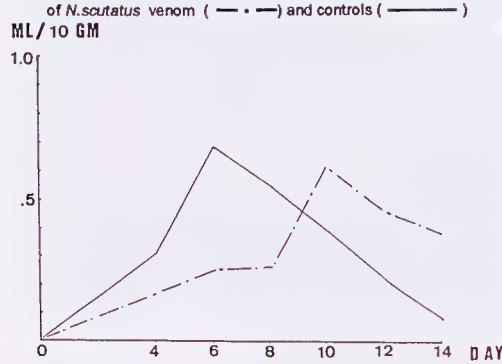


Fig. 4 Decay rate of dead neonate mice injected i.p. with 2 MLD of *O.scutellatus* venom (— • —) and controls (———)

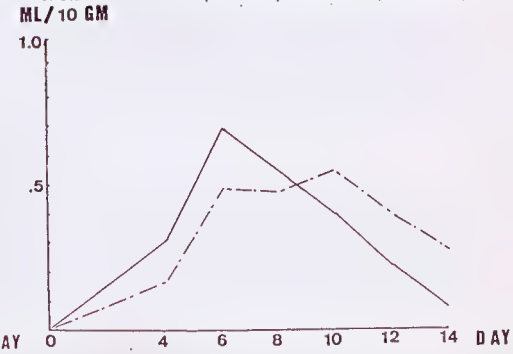


Fig. 5 Decay rate of dead neonate mice injected I.p. with 2 MLD of *P.australis* venom (— • —) and controls (————)

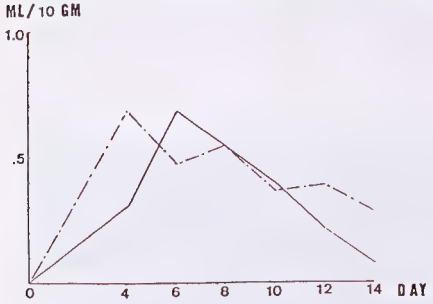


Fig. 6 Decay rate of dead neonate mice injected I.p. with 2 MLD of *P.porphyriacus* venom (— • —) and controls (————)

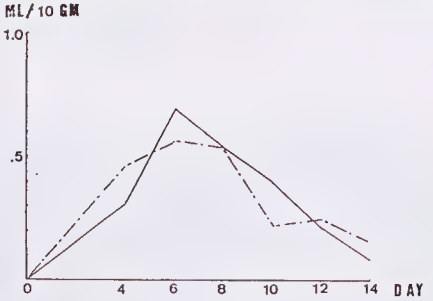
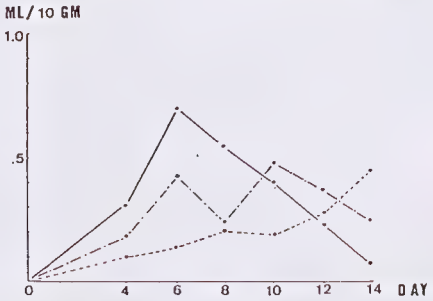


Fig. 7 Comparison of the decay rate of dead neonate mice injected I.p. with 2 MLD (— • —), 4 MLD of *V.lebitina* venom (— —) and controls (————)



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OBSERVATIONS ON THE TUSKED FROG *ADELOTUS BREVIS* (ANURA: MYOBATRACHIDAE)

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ABSTRACT

Male Tusk Frogs (*Adelotus brevis*) can form calling aggregations in late spring. A habitat utilised for spawning is dams which are fringed with emergent aquatic vegetation. Spawn can be laid amongst the leaves of sawsedge (*Gahnia sieberana*) or in "nests" which are probably constructed by the male frog. Nests were located on a ponds edge and consisted of saucer shaped spaces within organic debris. Males called from these nests during the day and more frequently at night. Males were observed to call while females were within nests prior to amplexus. Males were also detected calling from within the leaves of sawsedge. Spawn was laid within the leaves or in nests.

Unpigmented eggs were deposited in foamy masses and ranged from 148-485 and averaged 343 (N=12) per spawn. Eggs hatched within ten days. In nature eggs are protected by overhanging aquatic vegetation or the organic debris that forms the cover of the nest.

It is suggested that the enlarged head of the male Tusk Frog aids nest construction by pushing debris.

INTRODUCTION

Adult female frogs are predominantly larger than conspecific males (Shine 1979, Tyler 1992, pers. obs.). The Tusk Frog (*Adelotus brevis*) is unusual in that the adult male is larger than the female, having an enlarged head. While both sexes have tusks on the lower jaw the males are larger (Barker and Grigg, 1977).

The species is widespread, occurring in a variety of habitats from rainforests to flooded farm paddocks (Barker and Grigg, 1977). The males call is similar to that of the Brown Striped Frog (*Limnodynastes peronii*) (i.e. g-lik) and the species has a long breeding season (Barker and Grigg, 1977). Unpigmented eggs are deposited in a foamy mass, usually in a secluded site and the male may remain with the developing eggs (Barker and Grigg, 1977). The tadpoles darken upon hatching and eventually are black with a pale patch on the front of the head (Barker and Grigg, 1977). Tadpole life span is 71-84 days, grow to 28mm in length and metamorphlings measure 10mm (Barker and Grigg, 1977).

The present study investigates aspects of the general biology of the Tusk Frog. Descriptions are given on habitat, oviposition sites and fecundity. Hypotheses are advanced to explain the presence of tusks and the enlarged head of the male.

METHODS

Tusk Frogs were observed calling at Ourimbah, NSW (Lat: 33°17'S, Long: 151°18'E) on 31/10/92 - 1/11/92. Observations on calling males were made during the day and at night with the aid of a 100 watt 12 volt spotlight. Ten spawns were collected, held in separate containers (plastic clip bags) and the number of eggs determined by counting hatched tadpoles.

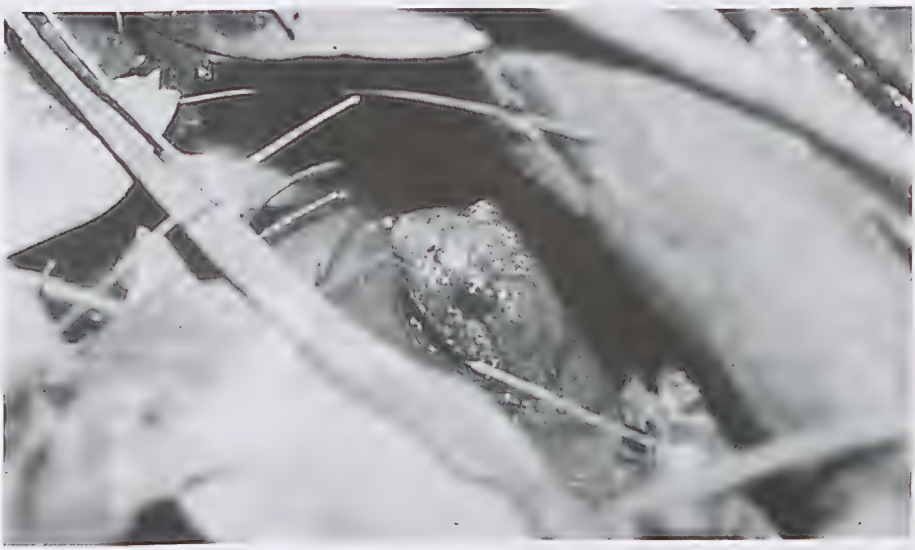
Tadpoles were retained in a 3.0m by 7.4m fibreglass pond. This pond was filled to a depth of 30cm with water which was increased to 1.3m after 45 days. The measured water temperature during that time ranged from 16-26°C. Tadpoles were fed boiled rice and bread.

RESULTS

Tusk Frogs mate in late spring and can spawn in constructed ponds. Male frogs were detected calling during the day and more frequently at night from either within the leaves of sawsedge (*Gahnia sieberana*) or saucer shaped clearings within organic debris positioned at the ponds edge. These clearings, referred to here as 'nests, were approximately 10cm in diameter and covered with leaves and twigs. Several males were observed in the sawsedge. One sat on top of a spawn and called with hind legs splayed while others called while floating on the water.

Two females were detected in separate nests which did not contain spawn. A large calling male was also detected in one of these nests (Figure 1). Some leaves from the top of this nest were removed to facilitate inspections. This disturbance caused the male to submerge for a few minutes. When another male was hand-held a distance of 4cm from the resident male and a female jumped out of the nest.

Figure 1. *Adelotus brevis* male in nest



Five spawns were located in nests, one of which was at the mouth of a Yabbie burrow. Six spawns were located within the sawsedge leaves and one was laid in 'culture', that is, in a plastic bag partially filled with water. Spawns hatched within ten days at 20°C and averaged 343 eggs (range 148-485, N=12). Hatchlings gained pigmentation within a day and were quite dark within two days. Tadpoles had benthic habitats and were coloured black with an off-white midnasal patch. The maximum tadpole size was 33mm (Figure 2). Metamorphosis occurred between 50-90 days and metamorphlings measured 10mm snout-vent length.

The vegetation in the immediate area was closed eucalypt forest which had several species of rainforest plant as understorey. The tree species located were redgum (*Angophora costata*), turpentine (*Syncarpia glomulifera*) and blackbutt (*Eucalyptus pilularis*). Understorey plants consisted of ironwood (*Backhousia myrtifolia*), sweet pittosporum (*Pittosporum undulatum*), sawsedge and *Lomandra longifolia*. The area had been logged.

Other animals detected in the immediate area included the Black Snake (*Pseudechis porphyriacus*), Lace Monitor (*Varanus varius*), Eastern Water Dragon (*Physignathus lesueurii*), Water Skink (*Eulamprus quoyii*), Perons Tree Frog (*Litoria peronii*), Leaf Green Tree Frog (*L.phyllochroa*) and Goldfish (*Carassius auratus*).

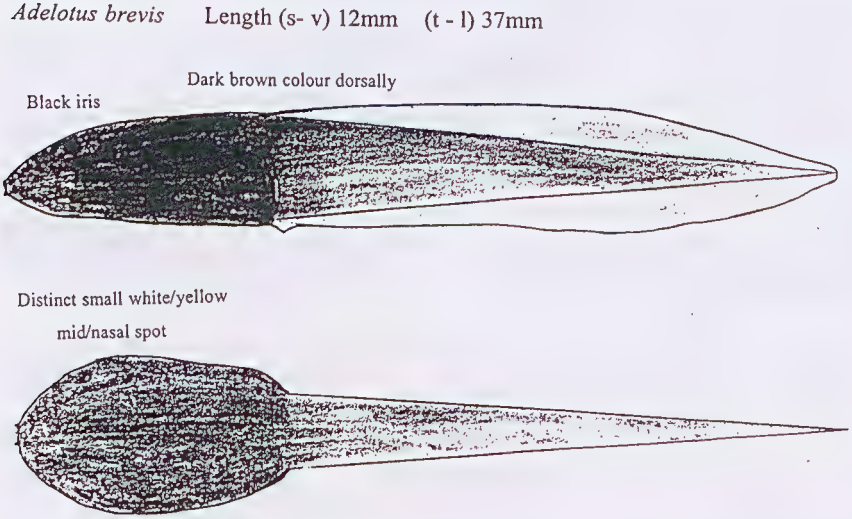
DISCUSSION

A reason suggested for the sexually dimorphic development of spines and tusks in male anurans is an adaptation to male combat rather than amplexus (Shine 1979). Sexual dimorphism in Tusk Frogs may also be an adaptation to nest construction. Male frogs probably construct the depression that forms the cup of the next by using their enlarged head to push organic material. Once constructed the male sits in the nest and calls. Eggs laid in nests have a greater chance of survival because the protective roof of leaves inhibits dehydration. This implies there is an advantage for enlarged heads in this species as nest building would be advantageous for the survival of tadpoles.

Spawns laid in nest would also reduce the risk of predation of unhatched eggs. Species such as the Brown Striped Frog (*Limnodynastes peronii*) and the Pobblebonk (*Limnodynastes dumerili*) have been observed to eat unhatched tadpole eggs (pers. obs.). Eggs laid in nests are protected by a physical barrier (organic debris) from the pond. Once hatched tadpoles presumably swim through the nest to the pond. A situation was observed at Nowra where spawn laid by the Brown Striped Frog in depressions at a ponds edge was consumed by large tadpoles when the water level of the pond rose (pers. obs.). This could be the fate of Tusk Frog eggs if they were not laid in nests.

Tusks are present in both sexes. The reason for their presence is unknown, although males have been observed biting in captivity (Giddings 1984) and induced to fight by biting in free range animals (Katsikiros pers. comm.). Male combat is a general feature of sexually dimorphic species of anurans in which males are larger than females (Shine 1979). Overt male aggression may occur at select sites which afford the most suitable environment for oviposition (i.e. clumps of sawsedge) where the density of male frogs is high.

Figure 2.



The observation here of a male and female evacuating their nest when presented with a rival male suggests that male combat may not be a regular behaviour in this species. Tusks may serve a purpose other than combat. The observation of males and spawn in nests indicated that males are segregated by organic debris. The situation in the clump of sawsedge was different, here a male called from on top of a spawn with its hind legs splayed to reveal the red coloured groin. Several other calling males were within this vegetation. Visual displays such as posture and colour may reduce fighting at crowded sites.

Breeding aggregations are a common feature of many Australian species of frog (pers. obs.). A reason for breeding aggregations is that males may be more likely to attract a mate than an individual as aggregations produce louder calls than individuals. The further a chorus travels the larger the area covered and hence the more gravid females are likely to be attracted. Individual calls in aggregations are staggered so that the caller contributes to the groups chorus yet retains his distinctive call which attending females can discriminate (Wells 1977).

Mate selection in Tusk Frogs may occur. This suggestion is supported by the observation of unclasped gravid females within nests with calling males. Females may enter a nest or a display area where several males are in close proximity and discriminate between potential mates. In both situations males which have larger heads would be advantaged as they could construct a larger

nest or gain the best position for spawning in the sawsedge. The situation of larger males being competitively superior to smaller males has been suggested by Duellman and Trueb (1986).

The dam which contained Tusk Frogs did not have any other species of the tribe Limnodynastini though the Brown Striped Frog and Pobblebonk are abundant in the general area (pers. obs.). Tusk Frogs and Brown Striped Frogs utilise similar oviposition site (pers. obs.). The species are phylogenetically 'close (Watson and Martin 1973) having similar calls and sexually dimorphic, larger males (pers. obs.). They are the only Limnodynastini to lay unpigmented eggs (Brown Striped Frogs lay unpigmented eggs in southern Victoria and Tasmania) (Littlejohn 1963). Segregation of these species was observed at Ourimbah.

Tusk Frog tadpoles took 50-90 days to complete metamorphosis. This is three weeks shorter than previously reported (Tyler 1992) and may be a result of the tadpoles being maintained in an uncrowded situation. Generally crowding in small volumes of water causes a lengthening of tadpole life (pers. obs.; Voigt 1991).

Crowding of hatchling tadpoles can cause a marked reduction in growth rate (pers. obs.). This mechanism may be advantageous for a species such as the Tusk Frog which lays its eggs in a nest on the edge of a pond. Hatchling Tusk Frog tadpoles were located at the study site stranded by a lowering of the level of the pond. If it rained and the ponds level rose then the tadpoles would be liberated from the nest. A paused growth rate in a crowded environment would allow a greater percentage of the clutch to survive temporary adverse conditions.

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DIET AND FOOD SELECTION IN A COMMUNITY OF SMALL GROUND-DWELLING LIZARDS AND FROGS IN SOUTH-EASTERN AUSTRALIA

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ABSTRACT

Diet and food selection of small ground-dwelling lizards and frogs in a eucalypt woodland in south-eastern New South Wales were examined. Food availability was measured by pitfall trapping and compared with diets determined by the analysis of stomach contents. Most species were catholic in their diet and selected items according to their apparent abundance on the ground, as measured by pitfall trapping. *Pseudophryne bibronii* consumed ants predominantly. The semi-arboreal lizards *Pseudemoia entrecasteauxii* and *Eulamprus heatwolei* chose flying insects in disproportionate numbers to those recorded in pitfall traps. The herpetofaunal community as a whole did not utilise prey resources proportionate to their relative availability (as measured by pitfall trapping).

INTRODUCTION

In recent years there have been a number of studies on the diet of temperate Australian lizards and frogs (Belmont 1977; Brown 1986, 1988, 1991; Crome 1981; Lunney *et al.* 1989; Pengilley 1971; Robertson 1981; Taylor 1986; Webb 1983; 1987a and b; Webb and Simpson 1985). However, few have examined diet at the community level in any great detail. Crome (1981) examined the comparative diets of four sympatric species of small ground-dwelling lizards in north-eastern New South Wales and concluded that these species were relatively catholic in their food selection. Similarly, Webb (1983), in a study of the diet of four species of frogs and nine species of lizards, concluded that all or most were opportunistic feeders. Belmont (1977) and Lunney *et al.* (1989) compared the gut contents of *Lampropholis delicata* and *Lampropholis guichenoti* and both concluded that the diets of these two species were diverse but generally similar.

There is a paucity of data on the relationship between food selection and availability for the herpetofauna of temperate eastern Australia. Brown (1988) provided the only detailed analysis of the diet of Australian lizards in relation to availability. Brown examined the food selection of *Pseudemoia entrecasteauxii* in south-western Victoria in relation to measurable availability within the habitat and found a significant correlation between the two.

In this study I examined the diet of a community of small ground-dwelling lizards and frogs in relation to the abundance of ground-dwelling invertebrates, as measured by pitfall trapping, and compared food availability and selection to some published data.

STUDY AREA

The study area was located in Bondi State Forest (37°10S149°05E), in the southern highlands of New South Wales, 30 km south of Bombala. The elevation of the area is approximately 900m asl. Climate is characterised by an average annual rainfall of 985mm with a mean summer minimum of 6.1°C and a mean maximum of 24.2°C, and a mean winter range of -3.7 to 10.3° (Hall *et al.* 1981).

Vegetation of the study area is predominantly open eucalypt forest of snow gum (*Eucalyptus pauciflora* Sieb. ex Spreng.), and mountain gum (*Eucalyptus dalrympleana* Maiden) with a low heath-like under-storey.

METHODS

Ground-dwelling lizards, frogs and invertebrates were sampled by pitfall trapping between 4 and 26 January 1981. Twenty pitfall traps were placed 5m apart in a 20x15m grid. Pitfall traps consisted of 5L plastic buckets containing a 10% formalin solution which were sunk flush with the substrate. Pitfall traps were inspected daily and emptied weekly.

Lizards and frogs were identified to species. Invertebrates were identified to order and sometimes family where possible. The length of whole invertebrates from pitfall traps, and from guts, were measured using an eyepiece micrometer while the length of part remains from gut analysis was estimated by comparison with whole animals. Fruits collected from the guts of three species of lizards were tentatively identified as *Persoonia chaenopuce* based on the presence of fruits on *Persoonia* plants and the absence of any other fruit bearing plants at the time of the study.

Taxonomic treatment follows (1986) for lizards, except for the recent revisions of Hutchinson (Hutchinson and Donnellan 1992, Hutchinson *et al.* 1990), and Cogger (1986) for frogs. Two species from the *"Leiolopisma entrecasteauxii"* complex were present in the study area, *Pseudemoia pagenstacheri* in the treeless grasslands/bogs and *P.entrecasteauxii* in open forest and woodland. The species involved in this study was clearly the latter based on morphology and habitat. The *Pseudophryne* sp. present showed only a limited degree of colour development in the groin and arm pits. I have therefore chosen to assign the name *Pseudophryne bibronii* rather than *Pseudophryne dendyi* to these animals.

The relationships between the abundance of prey groups in pitfall traps and in vertebrate stomachs were analysed using Spearmans rank correlation test (SAS 1987: PROC CORR procedure). A 5% level of significance is used in all tests. Comparisons were also made with published data on diet and food availability of *P.entrecasteauxii* (Brown 1988) and various *Pseudophryne* spp. (Pengilley 1971). Hutchinson and Donnellan (1992) indicated that the species involved in Browns study was *P.entrecasteauxii* sensu stricto.

The following acronyms were used for composite taxa: TOT (Total animals) and LIZ (Total lizards).

RESULTS

Four species of frogs and six species of lizards were caught in pitfall traps (Table 1). All were represented in small numbers except *Pseudophryne bibronii* which represented 47% of all captures. All lizards are active diurnal species (Cogger 1986, Jenkins and Bartell 1980) with the exception of *Nannoscincus maccoyi* which is cryptic and actively crepuscular or nocturnal, taking refuge under logs and leaf litter during the day (Jenkins and Bartell 1980, Robertson 1981). All species of frog are generally nocturnal in habit (Cogger 1986).

Food Availability

Numerically, the most abundant invertebrates in pitfall traps were ants (24.9%), adult beetles (19.6%), mites (12.2%) and spiders (11.6%) (Table 1). The frequency distribution of invertebrate groups caught in pitfall traps was compared with that recorded by Brown (1988) who used an index based on several sampling methods (Table 2). On ranked proportions, these two distributions were similar (R_s = 0.527, $p<0.01$) which indicates that pitfall trapping alone provided a reasonable assessment of available food resources, when compared with the more complex index of availability used by Brown (1988). However, flying and arboreal insects were clearly under-estimated using pitfall traps alone.

The dominant invertebrate length categories were 1-5mm (69.3%), 6-10mm (10.6%), 11-15mm (12.3%) with sequentially smaller proportions with increasing prey length (Table 3).

Gut Analysis

Four (9.1%) of the 44 guts examined were empty (2 of 21 *P.bibronii*, 1 of 1 *Limnodynastes peronii* and 1 of 2 *Lampropholis guichenoti*).

Pseudophryne bibronii

The majority of food items taken by *P.bibronii* were ants (83.8%), collembola (6.5%) and mites (4.1%) (Table 1). The remaining 10 prey groups used by *P.bibronii*, comprised only 5.6% of total food items. The frequency distribution of food items in the guts of P.bibronii was significantly correlated with prey availability, as measured by pitfall traps (R_s = 0.566, $p<0.01$) indicating that *P.bibronii* selected food in similar proportions to that occurring in the litter. Although ranked proportions were similar, ants were numerically far more abundant in guts (83.8% of all food items) than in pitfall traps (24% of all items).

Table 1. Invertebrate taxa recorded in pitfall traps and vertebrate stomachs

		FROGS				LIZARDS						
	pitfall traps	LE (n=1)	LP (n=1)	PB (n=21)	RS (n=1)	EH (n=5)	LG (n=2)	NC (n=3)	NM (n=3)	PE (n=6)	PS (n=1)	TOT (n=44)
ARACHNIDS												
Mites	159	0	0	30	0	0	0	0	0	0	0	30
Spiders	151	2	0	6	0	1	0	4	0	2	0	15
Scorpions	54	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEANS												
Isopods	13	0	0	5	0	0	0	0	1	0	0	6
Amphipods	9	0	0	1	0	0	0	0	0	0	0	1
INSECTS												
Cockroaches	2	0	0	2	0	0	0	0	0	0	0	2
Collembolans	92	0	0	47	0	3	0	6	3	0	1	60
Beetles	255	0	0	14	4	7	0	1	1	2	0	29
Beetle Larvae	24	0	0	0	0	0	0	0	0	2	0	2
Earwigs	4	0	0	0	0	0	0	0	0	0	0	0
Flies	39	1	0	4	1	0	0	1	0	10	1	17
Fly larvae	2	0	0	0	0	0	0	0	0	0	0	0
Bugs	31	0	0	3	0	1	0	0	0	4	1	9
Ants	315	0	0	610	1	0	9	0	0	1	1	622
Wasps	17	0	0	1	0	1	0	0	0	0	1	3
Moths	9	0	0	0	0	0	0	0	0	0	0	0
Moth larvae	9	1	0	0	0	0	1	0	0	0	0	2
Lacewings	0	1	0	0	0	0	0	0	0	0	0	1
Grasshoppers	34	0	0	0	0	0	0	0	0	1	0	1
Book lice	14	0	0	2	1	0	0	0	0	3	0	6
Unknown larvae	0	0	0	0	1	0	0	0	0	0	0	1
CHILOPODA	27	0	0	0	0	0	0	0	0	0	0	0
DIPLOPODA	36	0	0	0	0	0	0	0	0	0	0	0
MOLLUSCS	1	0	0	3	0	0	0	0	7	0	0	10
FRUITS	1	0	0	0	0	47	0	0	0	3	8	58
Total	1298	5	0	728	7	60	10	12	12	28	13	875

LE = *Litoria ewingi*, LP = *Limnodynastes peronii*, PB = *Pseudophryne bibronii*,
RS = *Ranidella signifera*, EH = *Eulamprus heatwolei*, LG = *Leiolopisma guichenoti*,
NC = *Niveoscincus coventryi*, NM = *Nannoscincus maccoyi*, PE = *Pseudemoia entrecasteauxii*,
PS = *Pseudemoia spenceri*, TOT = total lizards.

The frequency distribution of food items taken by *P.bibronii* was also correlated with that of total food items for all species combined (TOT) ($R_S = 0.810$, $p<0.001$). This positive relationship with TOT is not surprising given the dominance of *P.bibronii* in pitfall traps.

The frequency distribution of prey items taken by *P.bibronii* was compared with published data for *P.bibronii* and *P.dendyi* (Pengilley 1971). In this study, *P.bibronii* took prey in roughly the same

proportions as recorded by Pengilley for both *P.bibronii* (R_s = 0.673, p <0.01) and *P.dendyi* (R_s = 0.550, p<0.05) (Table 4).

The majority of food items taken by *P.bibronii* were 5mm or less in length (98.9%) (Table 3). In pitfall traps only 69% of all invertebrates fell into this category. There was only a weak, non-significant relationship between prey size range taken by *P.bibronii* and that recorded in pitfall traps (R_s = 0.650, ns). As *P.bibronii* is physically constrained, by body size, in the size of prey items it can consume, it is not surprising that most prey items fell into the smallest category. The relationship between PB and TOT (R_s = 0.868, p<0.01) was significant indicating that selection of prey sizes by *P.bibronii* and the community as a whole was generally similar. Again, this is not surprising given the numerical importance of *P.bibronii* in the community.

Other Frogs

Only single specimens of the remaining three frogs, *Litoria ewingii, L.peronii* and *Ranidella signifera* were caught in pitfall traps. Apart from listing the range of food items for these species no meaningful comparative results could be obtained.The single *L.peronii* stomach was empty. The *L.ewingii* stomach contained 2 spiders, a fly, a lepidopteran larva and a lacewing while the *R.signifera* stomach contained 4 beetles, 1 ant, 1 book louse and an unknown larva. Most food items taken by these animals were less than 5mm in length.

Pseudemola entrecasteauxII

The dominant food items in the *Pseudemoia entrecasteauxii* stomachs were flies (35.7%), bugs (14.3%), book lice (10.7%) and *Persoonia* fruits (10.7%) (Table 1). The frequency distribution of food items (excluding *Persoonia* fruits) was dissimilar to that recorded in pitfall traps (R_s = 0.326, ns), largely due to the high proportion of adult flies taken by *P.entrecasteauxii.* Flies, and other flying insects, were not adequately sampled by pitfall trapping. The three most abundant invertebrate food groups taken by *P.entrecasteauxii* (collectively 61% of total food items) represented only 5.8% of the available food items as measured by pitfall trapping. Conversely, the three most abundant groups in the litter (collectively 50%) represented only 11% of food items for *P.entrecasteauxii.*

The frequency distribution of *P.entrecasteauxii* food items (excluding *Persoonia* fruits) was similar to that of TOT (R_s = 0.516, p<0.05) and LIZ (R_s = 0.698, p<0.001). *P.entrecasteauxii* therefore selected food items in similar proportions to lizards as a whole and the entire community (including frogs).

The frequency distribution of prey items was compared with published data for *P.entrecasteauxii* (Brown 1988). There was only a weak relationship between the two distributions (R_s = 0.359, ns) (Table 2) largely due to the dominance of flies in this study and the higher numbers of other flying insects, and ants, taken by *P.entrecasteauxii* in Browns study.

There was a weak, non-significant relationship between prey size range taken by *P.entrecasteauxii* and that recorded in pitfall traps (R_s = 0.650, ns) indicating a tendency towards larger prey. The frequency distribution of prey size was similar to the composite taxa TOT and LIZ (both R_s = 0.868, p<0.01).

Eulamprus heatwolei

The most abundant food items in the *Eulamprus heatwolei* stomachs were *Persoonia* fruits (78.3%), beetles (11.7%) and collembola (5.0%). The frequency distribution of food items taken by *E.heatwolei* (excluding *Persoonia* fruits) was dissimilar (R_s = 0.232, ns) to that recorded in pitfall traps, largely due to the dominance of beetles and collembolans in their diet. Most of the beetles were ground active Carabidae and Tenebrionidae. A small lizard tail was also recorded in the stomach of one specimen.

The frequency distribution of food items taken by *E.heatwolei* was similar to the composite taxa: TOT (R_s = 0.546, p<0.05) and LIZ (R_s = 0.641, p<0.01) but only a weak relationship existed with *P.entrecasteauxii* (R_s = 0.396, ns).

Table 2. Comparison of relative prey availability recorded by pitfall trapping in Bondi S.F. and the composite index of Brown (1988).
The prey selection of *P.entrecasteauxii* in both studies is also compared.

	This Study (Pitfall Trapping) %	*P.entrecasteauxii* (This study) %	Composite Index (Brown 1988) %	*P.entrecasteauxii* (Brown 1988) %
Ants	24	4	9	15
Beetles	20	8	6	8
Mites	12	0	6	1
Spiders	12	8	4	8
Collembola	7	0	9	5
Scorpions	4	0	0	0
Flies	3	40	33	23
Millipedes	3	0	1	0
Grasshoppers	3	4	0	1
Bugs	2	16	5	23
Beetle larvae	2	8	1	0
Centipedes	2	0	1	0
Wasps	1	0	6	4
Isopods	1	0	3	4
Moths	1	0	3	3
Moth larvae	1	0	2	1
Booklice	1	12	1	0
Amphipods	1	0	0	0
Thrips	0	0	8	0
Worms	0	0	1	0
Lacewing larvae	0	0	0	2
Lacewings	0	0	0	1

Table 3. Distribution of prey size categories (%) taken by lizards and frogs compared to availability (as estimated by pitfall trapping).

			Prey Size Categories (length mm)				
	No. guts	Total Items	0-5	6-10	11-15	16-20	21-45
Pitfall Traps	-	1296	69.5	10.6	12.3	6.3	1.3
TOT	-	815	97.9	2.0	0.1		
TOT-PB	-	89	88.8	10.1	1.1		
FROGS							
L.ewingii	1	5	100.0				
P.bibronii	19	726	99.0	1.0			
R.signifera	1	7	100.0				
LIZARDS							
E.heatwolei	5	13	69.2	30.8			
L.guichenoti	1	10	90.0	10.0			
N.coventryi	3	12	100.0				
N.maccoyi	3	12	100.0				
P.entrecasteauxii	6	25	80.0	20.0			
P.spenceri	1	5	100.0				

There was only a weak relationship between the frequency distribution of prey size taken by *E.heatwolei* and that of potential prey recorded from pitfall traps (R_s = 0.650, ns) indicating a trend towards larger prey items. The frequency distribution of prey sizes taken by *E.heatwolei* was similar to that of the composite taxa TOT and LIZ (both R_s = 0.868, $p<0.01$).

Other Lizards

The remaining lizard species were caught in low numbers and therefore gut analysis did not provide statistically meaningful results. Nevertheless the food items taken are listed to allow comparison with previous studies. The three *N.maccoyi* stomachs contained collectively, slaters, collembola, adult beetles and snails. The one non-empty *L.guichenoti* stomach contained mostly ants with a single lepidopteran larva. The three *Niveoscincus coventryi* stomachs contained collectively spiders, collembola, adult beetles, and adult flies. The single *Pseudemoia spenceri* stomach contained an adult beetle, an adult fly, a bug, an ant, a wasp and 8 *Persoonia* fruits (Table 1).

Most of the food items taken by these species were in the smallest size category, except for a lepidopteran larva in the 10-15mm category taken by *L.guichenoti*.

Community-level use of food resources

A comparison of the frequency distribution of invertebrates caught in pitfall traps with the food items taken by all small vertebrates combined (TOT), revealed that the community as a whole did not utilise the full range of available food resources (R_s = 0.378, ns). Lizards (LIZ) also did not show a significant relationship with availability (R_s = 0.323,ns). A significant relationship existed for PB (R_s = 0.566, $p<0.01$), largely due to the dominance of ants in their diet and in pitfall traps.

Some invertebrates such as scorpions, earwigs, centipedes and millipedes were no taken as food despite their relative abundance in pitfall traps while others such as spiders, mites and adult beetles were under-represented in animal stomachs. Conversely, ants were selected in much greater proportions than were caught in pitfall traps.

DISCUSSION

Pitfall traps tend to over-sample active surface dwelling invertebrates and under-sample arboreal, aerial and sedentary invertebrate fauna (Greenslade 1964, Halsall and Wratten 1988). This imposes some bias in assessing the full array of food available to small ground-dwelling lizards and frogs. Nevertheless, careful interpretation of data from pitfall trapping can reveal patterns which help to describe food resource use particularly for those species that are demonstrably litter-layer dwellers.

Most of the lizard and frog species sampled in Bondi S.F. used a wide range of food resources. Some species, however, appeared to select particular prey groups in different proportions to their apparent availability, as measured by pitfall trapping. These differences can be related to both foraging behaviour and micro-habitat preference (Crome 1981).

P.bibronii showed a marked inclination towards small ants. Pengilley (1971) previously noted the dominance of ants in the diet of *P.bibronii* and several other species of *Pseudophryne*. The range of prey items recorded in this study was similar to that recorded by Pengilley for *P.bibronii* and *P.dendyi*. *P.bibronii* does not actively pursue its prey but tends to remain stationary and wait for prey to pass by (Pengilley 1971). Thus, it could be predicted from optimal foraging theory that *P.bibronii*, as a sit-and-wait forager, would take predominantly large and high quality prey (Lewis 1989, Toft 1981, 1985). This is clearly not the case. The feeding habits of *P.bibronii* and some other members of the genus appear to be dependent upon small, abundant and gregarious prey. Whilst *P.bibronii* may not be a strict ant specialist, as demonstrated for some South American frogs (Toft 1981) and for some desert lizards (Pianka 1977, 1989, Whitford and Bryant 1979), clearly, small ants are an important food resource. The gregarious (social) behaviour of these small ants provides an opportunity for *P.bibronii* to occasionally exploit rich patches of prey.

The larger, more arboreal, lizard species *P.entrecasteauxii* and *E.heatwolei* took proportionally more arboreal and aerial invertebrates such as flies, bugs and wasps than other species. *P.spenceri* also takes a high proportion of aerial and arboreal insects (This study, Brown 1986). The diets of these

three species reflect their more arboreal micro-habitats and behaviour (Brown 1986, 1988, 1991, Webb 1985, 1991).

Brown (1988) examined the diet of *P.entrecasteauxii* and related it to prey abundance as measured by a composite index of various sampling techniques. By using a wide range of insect sampling techniques Brown was able to construct a better index of prey availability than by using pitfall traps alone. Nevertheless, the frequency distribution of potential prey items as measured by pitfall traps in this study was not dissimilar to that recorded by Browns composite index. *P.entrecasteauxii* in both studies took a wide variety of food items, primarily insect material, with the dominant groups being mites, spiders, beetles, collembolans, flies and ants.

Brown (1991) recorded molluscs (large slugs) as the dominant food of *E.heatwolei* with various insects constituting the remaining food items. In this study, no slugs or other molluscs were recorded; beetles and collembolans were the numerically dominant food items. The difference between the diets recorded in the two studies may be attributed to the small sample size available for study at Bondi S.F. and differences in habitat between the two study areas. Furthermore, small insectivores with generally diverse diets such as *E.heatwolei* may utilise large, high quality prey, such as slugs, when available (Lewis 1989, Whitford and Bryant 1979, Toft 1981). Thus the composition of the diet of these animals may vary substantially depending upon the time of sampling.

Although few *N.maccoyi* stomachs were examined during this study the dominance of snails, collembola and slaters in the diet suggest that *N.maccoyi* feed predominantly on cryptic prey which occupy similar micro-habitats to that of *N.maccoyi* (Robertson 1981, Webb 1991). This is consistent with the study of Brown (1991) in Victoria where 61% of food items were terrestrial crustaceans (amphipods and isopods). Pengilley (1972) and Robertson (1981) previously noted the importance of terrestrial crustaceans in the diet of *N.maccoyi*.

Few *L.guichenoti* stomachs were examined. However, the dominance of ants is consistent with previous studies (Crome 1981, Lunney et al 1989) which found that ants, spiders and beetles were the dominant prey types. The diet of *L.guichenoti* was similar to that of *P.entrecasteauxii* which occupies similar micro-habitats (Jenkins and Bartell 1980, Webb 1991).

The use of *Persoonia* fruits by three species of lizards (*E.heatwolei, P.entrecasteauxii* and *P.spenceri*) was interesting in that the consumption of fruits has rarely been reported for Australian scincid lizards other than the larger *Tiliqua* spp. and their relatives (Webb 1987b, Webb and Simpson 1985).

Termites are important food items of lizards in arid and semi-arid regions of Australia and the rest of the world (Pianka 1989), but generally appear to be of less importance in temperate regions of Australia (Brown 1991). The importance of termites in the diets of the temperate Australian lizards is variable. Brown (1986) recorded large numbers of termites in the diet of *P.spenceri* in Victoria, attributing this to their preferred micro-habitat of logs and dead trees. Lunney *et al.* (1989) and Crome (1981) recorded relatively high proportions of termites in the stomachs of *Lampropholis delicata* and *Lampropholis guichenoti*. Taylor (1986) also recorded termites in the diet of *Ctenotus taeniolatus*. Termites may also be an important food resource for small myobatrachid frogs such as *Pseudophryne* spp. (Pengilley 1971, Webb 1983). At Bondi S.F., and elsewhere in the region, termites are generally absent from the diet of lizards and frogs (Webb this study and unpubl. data). This is surprising given that several species of termites (genera *Coptotermes, Heterotermes* and *Nasutitermes*) are present in the area and are commonly found in accessible locations in and under logs, stumps and dead trees (pers. obs.).

Some potential food items were avoided by lizards and frogs viz. millipedes, centipedes, scorpions and earwigs. This could be due to the toxic and/or noxious nature of these prey. Lewis (1989) noted the avoidance of millipedes by lizards and attributed this to the noxious secretion produced. However some large frogs, particularly *H.australiacus* (Webb 1983, 1987a) may consume such prey. Similarly, Brown (1991) has recorded the large semi-arboreal skink *Egernia saxatilis* feeding on scorpions. Other invertebrate taxa, namely spiders, mites and adult beetles were under-utilised.

Mites were probably too small to constitute a cost-effective food resource while many spiders and beetles were generally too large to be suitable food for the smaller ground-dwelling frogs and lizards.

It could be expected that the herpetofaunal community would utilise the full range of invertebrate food items available. This does not appear to have been the case, at least when measured by pitfall trapping alone. This was due to a number of reasons including the dominance of ants in the diet of *P.bibronii* and the high proportion of flying insects in the diets of the largest lizards, *E.heatwolei*, *P.spenceri* and *P.entrecasteauxii*. If these two influences are removed the range of prey taken by the remaining lizards and frogs generally resembles the range of items recorded by pitfall trapping. Furthermore, the presence of *Persoonia* fruits in the diets of the three largest lizards, particularly *E.heatwolei*, confounded the analysis of food selection.

Table 4. Comparison of relative prey selection of *P.bibronii* at Bondi S.F. and published data on *P.bibronii* and *P.dendyi* (Pengilley 1971).

	P.bibronii **(This study)** **%**	***P.bibronii*** **(Pengilley 1971)** **%**	***P.dendyi*** **(Pengilley 1971)** **%**
Ants	84	64	93
Collembola	6	20	1
Mites	4	5	2
Beetles	2	1	2
Spiders	1	0	0
Isopods	1	0	0
Flies	1	0	0
Termites	0	9	0

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OBSERVATIONS ON THE BIOLOGY OF THE PUNCTATE WORM-SKINK *ANOMALOPUS (VERMISEPS) SWANSONI* GREER AND COGGER, 1985 (SAURIA: SCINCIDAE)

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ABSTRACT

Observations on the small, specialised, fossorial and legless Punctate Work-skink (*Anomalopus (Vermiseps) swansoni*) both in captivity and of museum specimens show: 1. A patchy distribution but with a range extension to the north-west. 2. Exclusive or near exclusive termite feeding. 3. Production of two or three young in late summer. 4. Possible thermoregulatory behaviour. 5. A longevity of at least ten years. 6. An indeterminate conservation status.

INTRODUCTION

The endemic Australian genus *Anomalopus* is part of the monophyletic *Sphenomorphus* group of lygosomine skinks (Greer, 1989). The genus is currently recognised as being comprised of seven species of smooth scaled lizards, four of which are legless and the other three have much reduced limbs (Cogger, 1992). The four legless species have been included in a subgenus (*Vermiseps*) in recognition of their close phylogenetic affinities (Greer and Cogger, 1985). All four legless species *(A. (V.) brevicollis, A. (V.) gowi, A. (V.) pluto* and *A. (V.) swansoni)* are found in eastern Australia (Greer and Cogger, 1985; Ehmann, 1992; Cogger, 1992). All four species are medium to small, fossorial lizards having moderate to very limited distributions. All are poorly represented in museum collections. Very little is known of their biology apart from what can be inferred from museum specimens. *A.swansoni* has a distribution centred on the lower Hunter Valley and is the most southerly distributed species of the genus. A few details of the biology of the genus are found in Hutchinson (1993). Details of external morphology, osteology and systematics are described by Greer and Cogger (1985).

MATERIALS AND METHODS

Field work was carried out at numerous sites in the Hunter region and surrounding districts in NSW. Observations were made on six live specimens and 98 Australian Museum specimens. Intermittent observations were made on the live specimens over a period of several years.

GENERAL OBSERVATIONS

Two adult specimens of A.swansoni were found south of Murrurundi near Wingen (31°53'S, 150°52'E) on separate warm sunny days in mid-January 1988. One specimen (female) was beneath a small log, half concealed in the loose, loamy soil surface. The second specimen (male) was nearby under a small piece of wood in an area of open grazed pasture with scattered medium to moderately large trees. The female specimen measured 169(96+75)mm and weighed 4.95g. The male specimen measured 144(76+68)mm and weighed 2.28g.

Both specimens were medium brown with a pinkish tinge in dorsal colouration, slightly darker centres to each scale and a darker head. Some minute dark flecks were present on many dorsal scales. The original tail tips were only very slightly darker than the rest of the dorsum but 37mm of the tip of the female's tail was lost on capture and regrew an almost black colour. The snout region (as in many fossorial species) was slightly paler than the surrounding area and appeared to consist of a thickened dermis as well as a more highly keratinised epidermis as evidenced by the raised appearance of these scales and the slightly more robust scales sloughed from this area. The ventral surface colouration was translucent off-white with a slight pinkish tinge. Two embryos could be seen through the abdominal wall of the female, lying longitudinally, apparently with a single fold of the embryonic body. No eggshell or embryonic membranes could be discerned. There were 24 mid-body scale rows in the female and 26 in the male. There were 139 pairs of slightly enlarged mid-dorsal scales from parietals to a point above the vent in the female and 135 in the male. The

relatively small eyes have a movable and translucent lower eyelid. The rounded tail tip was covered by an enlarged cap scale.

In spite of its attenuate form the lizard has two rather short lungs which were measured by transillumination at 11mm and 12mm in length (left and right respectively). The heart rate also measured by transillumination was found to be 108/minute at an air temperature of about 28°C after being active. On subsequent occasions the heart rate was measured again at 109/minute at 28°C after being handled, and 34/minute at 25°C while apparently relaxed.

This species, like other skinks, has a parietal eye even though it has a subterranean mode of existence. The fact that some specimens have almost no external evidence of this organ may indicate that there is little current use for the eye.

Dissection of one specimen revealed the presence of nematodes (species unknown) in the gut. Certain nematodes are known to occur in termites (Barnes, 1963) but whether *A.swansoni* is a definitive host for one of these species is not known.

REPRODUCTION

Griffiths (1987), Hoser (1989) and Cogger (1992) all describe *A. (V.) swansoni* as being oviparous. However Greer and Cogger (1985), Wilson and Knowles (1988), Greer (1989), Ehmann (1992) and Swan (1990) all describe this species as the only member of the genus which bears live young. The species produces two to three live young at a time (Greer, 1989; Wilson and Knowles, 1988; and personal observation). Observations on live and museum specimens suggests that the species breeds only once in a season although whether the females give birth in successive years is not known. The scarcity of gravid females among the museum specimens would suggest that breeding occurs in alternate years.

The female gave birth about thirty days after capture to two live young, these measured 74.5(43+31.5)mm and 78.5(45+33.5)mm and weighed 0.345g and 0.385g respectively. The post-partum maternal weight was 2.38g thus giving a relative clutch mass of 31%. Gestation probably takes at least two months at room temperature (24-32°C), and the young are visible for at least one month prior to birth. The two young showed similar colour and habits to the adults although they had darker tail tips. The young began feeding on small termites within two or three days of birth (the exact day of birth was not ascertained). The young grew quite rapidly before reducing autumn temperatures slowed them down. One juvenile died in early spring after being attacked by a large soldier termite which embedded its jaws in the lizard's dorsum. A slight depression at the site of the bite was the only sign of the attack after removal of the mandibles although the lizard became very lethargic prior to succumbing. The second juvenile died in the late spring probably as the result of unseasonably low temperatures for an extended period before full recovery from the winter period. Although mating has not been observed in captivity, a pair were found lying adjacent and parallel to each other at a depth of about 10cm in mid-November when the female was also seen to have suffered a small bite shaped scar to the anterior dorsum. However no sign of pregnancy followed.

HUSBANDRY AND BEHAVIOUR

After the birth the two adult specimens were housed together in a four litre plastic ice-cream container with very small needle holes in the lid for ventilation, (to prevent termites escaping) and given similar friable, loamy soil to that in which they were found. They were maintained at room temperature without access to direct solar heating (which in hindsight seems to have been inadequate for the development of the young over a long winter). *A. (V.) swansoni* is said to feed on small, soft bodied insects (Griffiths, 1987); invertebrates (Wilson and Knowles, 1988); insects (Hoser, 1989); termites (Swan, 1990); termites, also crawling insects and insect larvae (Ehmann, 1992). Personal observation shows no evidence that this species feeds on anything other than termites. All worms, spiders, hemipterans, earwigs, centipedes and flies, all stages of the several small ant species offered were consistently refused and the only food species that were known to be taken were termites. All species of termite occurring in the area that were offered to the lizards were eaten, including *Coptotermes sp., Nasutitermes sp., Microcerotermes sp.* and *Protocapriter-*

mes sp. (as identified from Hadlington, 1987). All castes were eaten by the adult lizards including workers, pseudergates, alates, queens and soldiers.

No free drinking water was supplied and it seems probable that subterranean water loss rates are very low and that water requirements are met by feeding alone. It is possible that these skinks drank from the condensation which occasionally formed on the inside of their containers although there was no evidence to support this.

Regular weighing in captivity shows that *A.swansoni* feeds at temperatures down to about 17-18°C. Adults and young frequently plough through the surface layers of the soil but never remain on the surface for long at least in daylight, even when lighting is quite subdued. When disturbed they are very adept at retreating into the soil with a reverse sinusoidal motion.

The first observed slough in one juvenile occurred at 68/69 days and at 82/83 days in the other, each slough being preceded by almost a week of 'greying' when the surface layers were beginning to detach. The slough is detached in concertina fashion in much the same way as in *Ramphotyphlops*, leaving the body as a short ring. Sloughed skins were always found underground at a depth of several centimetres and sloughing was recorded only in the warmer months (between September 23 and May 11) at irregular intervals, the frequency varied from once every month to every two and a half months. There was no evidence of eating the shed skin.

The adult female has now been kept in captivity for over eight years with an increase of 4mm in snout-vent length and 11mm in regrowth of tail tip. Observations on the growth of the young would indicate that maturity may take at least two years. If this is the case then this species lives for at least ten years which seems remarkable for such a small skink. For comparison a number of the very large skinks are believed to live for 20 years and the medium sized *Cyclodina lichenigera* has been kept in captivity for seven years (Greer, 1989). The lizard appears to be in a healthy condition and responds vigorously when handled or exposed to light.

PRESERVED SPECIMENS

Sizes given in the literature for *A.swansoni* range from 100mm SVL (Cogger, 1992) to 107mm SVL (Greer, 1989) or 230mm total length (Hoser, 1989). The largest Australian Museum specimens measured 111mm SVL and 188mm total length. Of 104 (mainly Australian Museum) specimens examined 70 were large juveniles to adults, intact and measurable. The number of mid-body scale rows varied from 21-26 (range 22-26 according to Cogger, 1992). The average original tail lengths of 23 adult specimens (using an arbitrary SVL ≥70mm) was 79±5.8% (SD) of SVL, the value for 8 juveniles was 71±3.8% (SD) of SVL, indicating that the tail grows faster than the body. Original tail lengths of adults and juveniles varied from 63% to 94% of SVL. Excluding those with freshly broken tails, there were 26 specimens (45%) which had some regrowth of a broken tail. None of these regrown tails reached the average tail length, the maximum amount of regrowth being only 16mm even though some had lost about 50mm or more or original tail as calculated by comparison with intact specimens. This seems to indicate that tail breaks are uncommon (considering the longevity of the species) and that regrowth is very slow at least after the first few millimetres. The reason for this is unclear although one possibility is that regrown tails which do not have the skeletal structure of original tails, and therefore different muscular structure are not as functional as original tails e.g. in reverse subterranean locomotion.

Although a significant variation in relative tail lengths was found there was no obvious bimodal distribution and not enough specimens were sexed to demonstrate the presence of any sexual dimorphism.

Like many other fossorial reptile species *A.swansoni* has little taper to the tail. Presumably this helps to guide the tail end while in reverse locomotion, (a finely tapered tail would tend to buckle in this situation). The terminal scale on original or regrown tails in most cases is well rounded although in some it forms a small eminence on the blunt tail tip and in only one case (out of 55 examined) was a pointed tail tip found.

As in many other Australian skinks there is a degree of asymmetry of head scalation (Greer, 1993 and personal observation). Of 70 specimens examined 51 (73%) had the left parietal overlapping

the right and in 19 (27%) of cases the right overlaps the left. The significance of this is unknown but it may or may not be genetic in origin.

The gut contents of one specimen showed the remains of numerous termites among the detritus but no other discernible arthropods.

CONSERVATION

Cogger, Cameron, Sadlier and Eggler (1993) have not included any of the legless *Anomalopus* species in their list of Australian reptiles at risk. Gavin Ayre has found this species at a depth of one metre (personal communication) presumably following subterranean termite channels. If this is a common practice then this species may be better protected against cattle trampling and grazing effects than some other small fossorial reptiles. On the other hand the thermoregulatory behaviour of laying close to the surface in warm weather (personal observation) will make them more vulnerable to these effects.

Analysis of the records for all specimens in the Australian Museum together with personal observations show that the *A. swansoni* minimal polygon distribution covers an area of about 17,000 km^2 however much of this region is not suitable habitat. The northern limit of distribution is near Wingen (personal observation) (which is close to the watershed for the Hunter Valley), as far south as Pitt Town (Hawkesbury River according to Cogger 1992, or Berowra according to Swan 1990), as far west as Sandy Hollow and as far east as the Myall Lakes area. The distribution seems to be patchy but is locally quite common in some areas (Ehmann, 1992).

Suitable habitat includes open woodland, dry sclerophyll forest and coastal heathland with well drained, sandy soils (Wilson and Knowles, 1988; Cogger, 1992; Ehmann, 1989). In spite of its limited distribution and the fact that an increasing proportion of its habitat is becoming subject to agriculture and urban development, the species is thought to be secure (Ehmann, 1992). It may be expected that in urban and agricultural development areas subject to heavy termite or other insect pest eradication programs, this species is likely to be adversely affected. This species has not been found in dense forests, heavy soils, very rocky areas, areas subject to flooding, or intensively farmed localities. *A.swansoni* has been recorded from the protected habitats of Muogamarra Nature Reserve, Milson Island and adjacent to the Myall Lakes National Park. Further field work may well prove its presence in other protected areas. The species is not mentioned in a survey of the herpetofauna of the Myall Lakes area by Markwell and Knight (1986).

Although numerous sites were examined in the Central Coast and Hunter regions, mainly between the Hawkesbury River in the south and Myall Lakes in the north-east, no new localities were found for the species except the one at Wingen.

More systematic collecting and more detailed observations are required in order to gain the information needed to make meaningful planning decisions about the status and conservation of *A.swansoni*.

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GULL-BILLED TERN PREDATION ON DRAGONS: A POSSIBLE RANGE LIMITING FACTOR FOR ARCOONA DRAGONS (*CTENOPHORUS FIONNI*)?

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ABSTRACT

Significant predation pressure on dragons by nesting Gull-billed Terns was recorded around temporary lakes in northern South Australia. Predation by terns was considered to potentially be an important factor in restricting the distribution of the Arcoona Dragon, which was not found in the vicinity of known tern colonies. The implications of greater nesting opportunities for terns and gulls to arid zone agamid populations with restricted ranges, are briefly discussed.

INTRODUCTION

Ctenophorus fionni is a medium sized agamid which inhabits crevice forming rock outcrops on Eyre Peninsula and the central northern regions of South Australia (Houston1978). Male *C.fionni* exhibit highly variable colouration and patterning which was used by Houston (1978) to delineate six geographic races. The "northern" race, characterised by striking red flank barring, is found on the Arcoona Tableland and hence is known as the Arcoona Dragon.

The Arcoona Tableland is an elevated region of gibber plains in the Woomera region of northern South Australia (Fig. 1). Two large salinas, Lake Torrens and Island Lagoon, border the eastern and western margins of the plateau respectively. Several small temporary lakes, referred to as the Arcoona Lakes, receive runoff from the localised internal drainage within the Arcoona Tableland. Rock outcrops suitable for crevice dwelling lizards, are largely restricted to the cliffed margins of the Arcoona Lakes and the large salinas.

This paper documents significant predation of agamids by Gull-billed Terns (*Gelochelidon nilotica*) which nest in colonies on islands within the Arcoona Lakes. Gull-billed Terns visit inland regions when favourable seasons provide nesting opportunities on islands in temporary lakes. Nesting Gull-billed Terns feed largely on lizards (Cain 1933), including dragons and skinks (P. Langdon, pers. comm.). A mechanism is proposed whereby avian predation, centred upon the Arcoona Lakes, may restrict the distribution of Arcoona Dragons.

METHODS

Rock outcrops throughout the Arcoona Tableland were surveyed for reptiles from 1990-1994. Particular attention was paid to the cliffs associated with many of the Arcoona Lakes, which were all visited several times in favourable warm weather throughout the study period. Records of Arcoona Dragons and Gidgee Skinks (*Egernia stokesii*) were also retrieved from the South Australian Museum. The local distribution of *E.stokesii*, another medium-sized crevice dweller, is largely restricted to rocky regions (pers. obs.) and hence may indicate potentially suitable habitat for *C.fionni*. Notes were also made on the distribution of food resources and potential predators of agamids throughout the Arcoona Tableland.

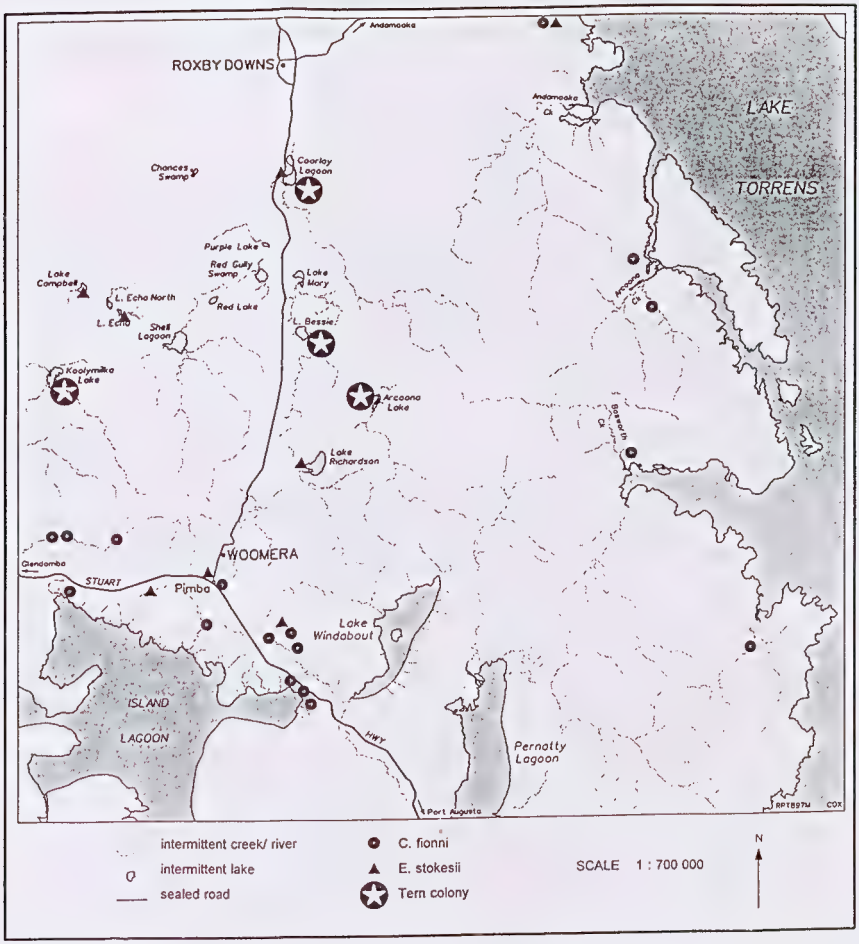
RESULTS

The Arcoona Dragon was recorded from the cliff-lined margins of Lake Torrens and Island Lagoon and several rocky creeks on the Arcoona Tableland (Fig. 1). No Arcoona Dragons were recorded from the cliffs associated with the smaller lakes within the Arcoona Tableland, although the middle reaches of Rocky Creek, which flows into Lake Richardson, supported a dense population. Horizontal rock crevices were used as shelter sites at most localities, which is typical of other *C.fionni* populations (Houston 1978, Gibbons and Lillywhite 1981), although some individuals also sheltered under boulders on gibber plains in the vicinity of rock ledges. Gidgee Skinks were more widespread than Arcoona Dragons and also inhabited the cliff-lined shores of several of the Arcoona Lakes (Fig. 1). Despite being more catholic in their choice of rock outcrops than *C.fionni*, the presence of Gidgee Skinks at several of the Arcoona Lakes supports the thesis that these cliffs

provide suitable habitat for *C.fionni*. Paucity of suitable habitat is therefore unlikely to explain the limited distribution of Arcoona Dragons.

Arcoona Dragons were observed feeding on Hymenopterans and Dipterans which were attracted to flowering plants, particularly Blue Rod (*Stemodia florulenta*). This plant species is found in drainage lines and swamp or lake margins throughout the Arcoona Tablelands. *C.fionni* have an unspecialised diet and have also been recorded feeding on beetles, grasshoppers, spiders, ants, ticks and other *C.fionni* (G. Johnston, pers. comm.). The distribution of *C.fionni* within the Arcoona Tableland is therefore unlikely to be limited by food availability.

Figure 1. Sites on the Arcoona Tableland where *Ctenophorus fionni*, *Egernia stokesii* and Gull-billed Tern colonies were recorded.



Several predators, namely Wedge-tailed Eagles (*Aquilla audax*), Brown Falcons (*Falco berigora*), Mulga Snakes (*Pseudechis australis*), Western Brown Snakes (*Pseudonaja nuchalis*) and Goulds Goannas (*Varanus gouldii*), have been observed preying on dragons throughout the study area. These predators are widespread habitat generalists (pers. obs.) and hence are unlikely to restrict prey species to certain localities. Gull-billed Terns, however, feed predominantly around fresh-water lakes which provide them with nesting opportunities. Inspection of tern colonies on Coorlay Lagoon on 8 October 1990, 8 December 1990 and 1 November 1992 yield 13, 6 and 11 dragon remains

respectively. All of the dragons that could be positively identified were immature Bearded Dragons (*Pogona vitticeps*). The entire tails of six Bearded Dragons measured between 107mm and 128mm which suggests that the terns were selecting dragons of total length between 180mm and 225mm (J. Read unpub. data). These terns have also been observed taking Lined Earless Dragons (*Tympanocryptis lineata*) near Port Augusta (Cain 1933) and Four-pored Earless Dragons (*Tympanocryptis tetraporophora*) near Coorlay Lagoon (pers. obs.). Although no direct evidence of predation on *C. fionni* was recorded, all of the adult female and many of the adult male Arcoona Dragons measured on this survey were within the size range of agamids recorded from the diets of Gull-billed Terns.

Gull-billed Tern nesting colonies were recorded on Arcoona Lake, Coorlay Lagoon and Lake Koolymilka, and non-nesting birds also visited most of the other Arcoona lakes including Richardson, Mary, Bessie, Purple and Shell (Fig. 1) following the 1989 fillings of these lakes (pers. obs.). Several of these other lakes provided potential nest sites for tern colonies and may have hosted tern colonies in the past. However the scarcity of low flat islands and the shallow nature of the larger salinas restricts the nesting opportunities for Gull-billed terns at these localities.

DISCUSSION

Suitable climate, habitat and food supplies are apparently available for Arcoona Dragons in the clifflines surrounding the small internal lakes in the Arcoona Tableland. Arcoona Dragons have therefore either never reached the Arcoona Lakes, or their absence is attributable to a localised inhibiting factor. Although adult *C.fionni* defend relatively small territories (Gibbons and Lillywhite 1981), site fidelity alone cannot explain the limited distribution of Arcoona Dragons. *C.fionni* occupy many relatively isolated rock outcrops throughout their range (Houston 1978), including sites west, south and east of the Arcoona Lakes and in the same drainage system as one of the Arcoona Lakes. Colonisation of remote rock outcrops probably occurs by juveniles, which have less restricted habitat requirements (Gibbons and Lillywhite 1981) and may be forced from their natal regions by inter-specific aggression or competition.

Location specific predation is a plausible explanation for the restricted range of Arcoona Dragons. The impacts of localised predation on Arcoona Dragons is likely to be magnified by the low vagility of this species (Gibbons and Lillywhite 1981) which would hamper the rapid replacement of exterminated populations. Most predators of dragons are widespread throughout the Arcoona Tableland with the exception of Gull-billed Terns which visit the region following periodic flooding events. The role of aerial predation as an important force driving the evolution of *C.fionni* dorsal colouration was reported by Gibbons and Lillywhite (1981). Predatory birds, such as Gull-billed Terns, may therefore significantly impact the ecology of Arcoona Dragons.

Predation pressure on dragons by Gull-billed Terns is likely to be most intense around small temporary lakes which are the favoured nesting sites of tern colonies in the Arcoona region. Juvenile Bearded Dragons are the predominant, although not obligate food source, for Gull-billed Terns in the study area. Gull-billed Terns will probably prey on any medium-sized lizards, particularly those basking in prominent positions. Most lizards, including Gidgee Skinks, do not bask in unprotected areas (pers. obs.) and hence would be difficult prey for birds such as terns which hunt on the wing. Arcoona Dragons, however, would probably be easy targets for Gull-billed Terns because they bask and display in exposed, prominent locations. Intense predation pressure during nesting periods, which often coincide with active periods for dragons, could significantly impact Arcoona Dragons because they are largely restricted to rock ledges around lakes. Populations of other agamids such as *P.vitticeps* and *Tympanocryptis spp.* are not as vulnerable to intense localised predation since these species are widespread throughout more common habitats in the region (Read, 1995). Depleted populations of these species with less specialised habitat requirements can be readily augmented by immigration of individuals from surrounding regions. In addition, adult *P.vitticeps* are long-lived and exceed the maximum prey size of Gull-billed Terns and hence sporadic juvenile predation events are easily absorbed by the population.

Silver Gulls (*Larus novaehollandiae*) are considered to be the greatest predation hazard for another arid zone agamid, the Lake Eyre Dragon (*Ctenophorus maculosus*) (Mitchell 1973). Silver Gulls also nested on the Arcoona Lakes and, although their diet was not investigated, they may also take

dragons and hence influence *C.fionni* distributions. Predation by terns and possibly gulls could account for the restricted range of Arcoona Dragons.

The long-term conservation prospects of restricted arid zone agamids could therefore potentially be influenced by an increase in the density, duration or number of nesting sites of terns and gulls. Tern and gull predation on agamids is currently limited to occasional periods when flooding rains provide suitable nesting opportunities, and is concentrated around lakes with suitable nesting islands. However, this balance may change if rainfall patterns change appreciably or if water storages are developed in areas which support restricted small agamid populations. Global climate change, accelerated by the greenhouse effect, is predicted to result in an increase in the frequency of summer floods in northern South Australia (Gordon *et al.* 1992) which may in turn increase the temporal and spatial breeding opportunities for island nesting birds. Increased avian predation may therefore become one of many mechanisms that result in a change in vertebrate distributions as a result of climate change (Stott 1994).

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NOTES ON *CARLIA AMAX* (SCINCIDAE)

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Carlia amax is a small (max. SVL = 40mm) terrestrial skink occurring throughout the Kimberley region of Western Australia, the wet-dry tropical region of the Northern Territory and north-western Queensland (Horner 1991). In this note I describe some field observations of the habits and behaviour of *Carlia amax* recorded during a 16 day visit to Nitmiluk (Katherine Gorge) National Park in the Northern Territory between 2-18th February 1995. *C.amax* was a common inhabitant of sandstone outcrops throughout the park, particularly those lining wet season creeks. It often occurred in sympatry with the skinks *Cryptoblepharus plagiocephalus, Ctenotus coggeri, Ctenotus inornatus, Eulamprus isolepis* and *Morethia ruficauda.* Observations of *C.amax* were facilitated by their apparent tolerance to human presence, permitting one to observe the skinks at quite close quarters.

SEXUAL DICHROMATISM AND REPRODUCTION

Species of *Carlia* are known to exhibit quite distinctive forms of permanent and semi-permanent sexual dichromatism (Greer 1989, Horner 1991). Breeding male *C.amax* have a more intense patterning, a copper-green head, and reddish tinge on the flanks (Horner 1991). None of the males observed (n = 7) exhibited the latter two features but were brighter in colour with more intense patterning than females. It was noted that juveniles more closely resembled the female colouration and lacked the brighter (mature) male markings.

All of the adult females captured (n = 11) were heavily bodied suggesting they were gravid. This observation is consistent with the species known reproductive season (September-April: James and Shine 1985; January: enlarged testes, ovarian follicles and oviposition, Shea *et al.* 1988; November-March: gravid females, Horner 1991). Several hatchlings were observed.

ACTIVITY

C.amax was active during the hottest part of the day in areas where shade was available, but otherwise (e.g. in exposed sandstone outcrops) its activity period was essentially crepuscular, probably a result of the extreme ground level day-time temperatures. Individuals were observed to be active as late as 7:55pm (CST) by which time the area was completely dark. Rock temperatures generally remained well above ambient late into the night. Horner (1991) remarks that *C.amax* have occasionally been observed active after dark but that it is not a common occurrence. I observed the movements of one particular female (recognisable by her regenerated tail) over a two day period, during which time her activities appeared to be largely confined to a patch of semi-shaded leaf litter of dimensions 5 x 3m. She foraged and basked in dappled sunlight intermittently throughout the day. The only other conspecific observed in the patch was a juvenile, but interactions between the two were not observed.

TAIL-WRIGGLING

Many *Carlia* species tail-wriggle (see Horner 1991, Ehmann 1992). In *C.amax* this takes the form of a slow propagating wave down the tail which is curled back on itself. Ehmann (1992) observed in *C.amax* that the 'tail is lashed slowly from side to side'. I observed both juvenile (SVL ≈ 25mm) and adult *C.amax* tail-wriggling when foraging and moving about amongst leaf litter. I did not observe it during courtship (see below). When approached closely or pursued, tail-wriggling ceased as the lizard fled. It was also not exhibited when lizards were still for extended periods (e.g. when basking). The significance of this behaviour in *C.amax* was not immediately obvious, however given the contexts in which it occurred, it is consistent with a predator distraction or diversion behaviour (G.A. Torr, pers. comm.). Regenerated tails were observed in some individuals. Whittier (1993) observed tail-wiggling in *C.rostralis* in several different contexts and stated that its function in this species was unclear.

DIET

While several species of ants were very common amongst the leaf litter and frequently encountered by individual *C.amax*, these were ignored, and lizards were never observed to consume or attempt to consume them. In contrast, houseflies (*Musca domestica*) were regularly snapped at in the course of foraging, with varying success. Dragon flies were also snapped at, but their large size would probably render them unsuitable as food items and I suspect they were mistaken for flies. On several occasions individual *C.amax* were attracted to flies which had gathered around a wound on my leg.

COURTSHIP

I describe what appeared to be courtship behaviour in an adult male-female pair of *C.amax*. These observations occurred between 6:58am-7:42am on 14th February at the base of a sandstone outcrop on the bank of Seventeen Mile Creek crossing (near the northern boundary of the park). During this time the bank was in complete shade and was yet to receive first morning light. Air temperature at ground level was 22°C.

The male was initially observed pursuing the female through leaf litter. The male was more vividly coloured than the female and slightly larger, enabling them to be readily distinguished. During the pursuit, the female stopped and the male continued to approach her from the left side but more slowly. When the male was within 2cm of her head, the female commenced a series of head 'bobs' which consisted of the head being slowly raised and then lowered to its normal resting position. It was repeated three times. This was done in conjunction with arm 'waving' which consisted of a simple raising and then lowering of the left forelimb to its resting position (there was no apparent lateral movement of the limb). This was also repeated three times but was not coordinated with the head movements. The male responded by lowering its snout flush to the substrate, tilting and expanding its dorsal surface. This crouched posture persisted until the female moved forward a short distance (about two body lengths). The male responded also by moving forward until its head was several millimetres from the female's vent. It then proceeded to lick the female's vent some 6-7 times, the female remaining still. After several minutes the female again raised her head and simultaneously raised and then lowered her left forelimb. She then moved a further 10cm away from the male and rested on a piece of exposed sandstone. The male after some 30 secs, slowly approached the female from the left side until their heads were about 1cm apart. The female again raised and lowered her head several times and then raised her left forelimb, this time holding it motionless in the raised position for more than 10 secs before lowering it. The male then fled from the female. The female remained in the immediate vicinity where the encounter had taken place, foraging and later basking once sunlit patches had developed. Following the encounter, head 'bobbing' and arm 'waving' behaviour were not exhibited by the female.

This encounter has a number of similarities with the observed courtship behaviour of *C.rostralis* as described by Whittier (1993). In particular, the head and limb movements of the female, the crouching posture and tongue flicking of the male have been observed in *C.rostralis* and interpreted variously as assertive/submissive displays and as indicators of sex recognition (see Whittier and Martin 1992, Whittier 1993). In contrast to the behaviour displayed by *C.amax*, Whittier (1993) made no mention of the forelimb being held in the raised position but did observe tail-wiggling in *C.rostralis* during courtship. It is also very different from the combat behaviour recorded in *C.rubrigularis* (see Torr 1994).

MITE PATCHES

Most adult specimens had small, conspicuous, axillary patches of red mites located on either side of the body. Patches were between 2-4mm in diameter. They did not appear to adversely affect individuals.

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HERPETOLOGICAL NOTES

OCCURRENCE OF *TILIQUA SCINCOIDES* (HUNTER, 1790) ON MAGNETIC ISLAND, QUEENSLAND

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INTRODUCTION

As of 1995, there were no published records of the occurrence of the Eastern Blue-tongued Skink *Tiliqua scincoides* on Magnetic Island, North Queensland (Low, 1978; Various authors 1977). Furthermore at the time of writing (1995), there are no specimens lodged at the Queensland Museum from Magnetic Island, although specimens have been found on nearby parts of the mainland (Patrick Couper, pers. comm.). This paper records the finding of an adult male *T.scincoides* from the vicinity of Endeavour Creek, western Horseshoe Bay, Magnetic Island (19°7S X 146°51E).

OBSERVATION

Date: 21st March, 1994
Time: 13:10 hours (Eastern Standard Time)
Weather conditions: 29°C, slight south-west breeze, approx. 90% cloud cover, 68% relative humidity. (Measurements taken using whirling psychrometer).
Habitat: Open lowland flat with isolated *Triodia stenostachya* and speargrass overstory. Immediately adjacent to this semi-cleared area was a narrow humid corridor of sloped deciduous monsoonal forest with abundant vine thickets and granodiorite outcroppings.
Notes: The *T.scincoides* was seen moving amongst grasses within the intergrade zone of the above habitats. The lizard measured 505mm (total length). Its pattern and colour was similar to that of specimens from the nearby Townsville area (pers. obs.). The lizard was photographed (see Figure 1) and released.

DISCUSSION

T.scincoides is perhaps Australia's best known skink (Hoser, 1989; Worrell, 1969). It is difficult to explain why such a large and conspicuous species has not previously been detected on Magnetic Island. This is particularly in view of the large permanent human population on the island.

Sue Jones, a long term resident of the Island and experienced wildlife observer, had no prior knowledge of the species on the Island. Shea (1982), citing other references, suggested that some insular populations of *Tiliqua gigas* have been introduced; possibly by trade vessels. It is possible that the occurrence of *T.scincoides* on Magnetic Island has resulted from a relatively recent introduction by humans. Further investigation into Magnetic Island *T.scincoides* is required to determine if the lizards there are in fact a long established insular population.

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Figure 1. *Tiliqua scincoides* from Magnetic Island.



A PREVIOUSLY UNRECORDED PREY ITEM FOR THE GIANT CAVE GECKO (*PSEUDOTHECADACTYLUS LINDNERI*)

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The Giant Cave Gecko (*Pseudothecadactylus lindneri*) was first described in 1975 from the rugged sandstone plateau country of the Western Arnhemland region of the Northern Territory, with a subspecies or closely related species (*Pseudothecadactylus cavaticus*) occurring further west in the Kimberley region of Western Australia (Cogger, 1975; Smith, 1989). Given the recent discovery and remote and rugged habitat, it is not surprising that the ecology of this large and attractive gecko is poorly documented (Greer, 1989).

Pseudothecadactylus lindneri are most active on drizzly evenings during the wet season, when they emerge onto open rock faces to feed (Cogger, 1992). They are also quite active during the much cooler dry season nights, often venturing well away from the protection of caves and crevices to forage out on large boulders, exposed rock faces, amongst leaf litter on the ground, and on the trunks of small trees growing at the base of the escarpment (Bauer, 1990a; Sadlier, 1990; G. Husband, pers. obs.). They have been observed active many metres up in flowering trees (most commonly *Syzygium forte, Ficus platypoda* and *Memecylon arnhemensis*) in monsoonal forests growing next to the escarpment, possibly feeding on insects attracted to the blossoms (Ian Morris, pers. comm.).

The diet of the Giant Cave Gecko has been reported to include insects, spiders and geckos of the genus *Gehyra* (Bauer, 1990a; Cogger, 1975, 1992; Ehmann, 1992; Schmida, 1985; Swanson, 1987).

On 14 June 1994 at approximately 1330 hours a noteworthy dietary observation was made while undertaking fieldwork for the Territory Wildlife park in the Arnhemland Aboriginal Reserve. While searching a cave in a sheltered gorge in the main escarpment approximately 6 km SW of Oenpelli, an adult male Giant Cave Gecko was observed active on the ceiling approximately 2m from the ground. The cave was about 10m deep by 2m high, with the humidity so great that our clothing was drenched in minutes. On closer inspection, a small object was observed protruding from the mouth. After a short chase, the lizard was captured, at which time it tried to bite the captors hand, revealing a recently consumed frog in the mouth. The frog was an adult Masked Frog (*Litoria personata*), another Western Arnhemland endemic. Neither individual was retained.

A further search of the cave revealed between 50 and 100 Masked Frogs both active and sheltering in crevices, but no additional Giant Cave Geckos. An unidentified species of cricket, extremely abundant in this cave as well as many others in the area would undoubtedly make up a large part of the geckos diet.

While vertebrates have been reported as occasional prey for a number of gecko species worldwide, most such food items have been lizards, especially skinks and other geckos (Bauer, 1990b). Frogs have rarely been reported as gecko prey.

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FISH AS PREY FOR THE SLATEY GREY SNAKE (COLUBRIDAE)

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The Slatey Grey snake (*Stegonotus cucullatus*) is a moderately large, 1.3 metres total length, colubrid snake, found in mesic habitats in northern Australia (Cogger, 1992). It has been reported as feeding predominantly on reptile eggs, however it has also been found to eat lizards and occasionally frogs (Shine, 1991a and b, 1994).

On Saturday 30th April 1994, an adult Slatey Grey snake (*Stegonotus cucullatus*) was observed to capture and attempt to consume a small rainbow fish from a shallow pool at Scott Creek, 60km south east of Darwin. Scott Creek flows into the Adelaide River to the east. The fish was regurgitated when the snake was disturbed by the bright light of a flash on a camera and human movement. After the wet season, as the flood waters subside, a number of ephemeral pools form the creek. Many fish are found in these pools. Below the Scott Creek crossing on the Marrakai Road 55km ESE of Darwin, is an ephemeral pool containing hundreds of thousands of fish, many only a few centimetres long. The density of fish is so great that many are forced from the pool by the extensive biomass and die on the bank. They provide a potentially plentiful food source at that time of year for terrestrial predators. The Slatey Grey snake was observed to catch the fish underwater in this pool.

It is interesting that anuran prey have not been found to be a large component of the diet of the Slatey Grey snake as there are many frog species in the mesic habitat which this snake inhabits.

The Scott Creek site is also a focal point for little file snakes (*Acrochordus arafurae*) with over 100 individuals visible on some nights, including many gravid females. File snakes appear to be slowly moving upstream through the culvert which acts as an artificial funnel for their movement.

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NOTES ON EARLY DEVELOPMENT IN A HATCHLING-ASSISTED FRILLED LIZARD (*CHLAMYDOSAURUS KINGII*)

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On December 2nd, 1993 a gravid female Frilled Lizard (*Chlamydosaurus kingii*) was presented to the Queensland Reptile & Fauna Park at Beerwah, south-east Queensland. The lizard originated from Beerburrum Forest in the Mellum Creek area (latitude 26°51S, longitude 153°01E) and on arrival was emaciated, with head injuries probably the result of being hit by a car. The donation of this lizard caused great excitement, as no *C.kingii* had been reported from this area since 1978.

The lizard was examined by our consulting veterinarian, Dr Angus Young, who recommended no formal treatment, apart from a stress-free environment to promote recovery. She was placed in a grassed enclosure, with hollow logs as shelter and her progress was monitored continually.

The lizard suffered from lack of co-ordination and walked in circles. This seemed to rectify itself over several days, but she then began to deteriorate. Dried blood was observed around her nose and she refused to eat voluntarily. She eventually lost consciousness and, because of her gravid condition, she was placed in an incubator until she died on December 30th, at which time a caesarean section was performed. Ten eggs were found in her oviducts, but only eight appeared viable and were removed. These were incubated at 29-31°C, apart from an uncontrollable peak of 40°C from December 26th, 1993 to January 1st, 1994. After 10 days only five eggs appeared viable and by March 4th, 1994, only two healthy eggs remained.

The first egg slit was noticed on March 19th. After several hours the neonate had not emerged and appeared weak and lethargic, even having difficulty raising its head. It was then removed from the egg, but although the eyes were open, there was no sign of breathing. Consequently, mouth-to-nose resuscitation was performed until the lizards lungs expanded. Breathing was voluntary from that point, although the young lizard still appeared close to death. Hence, there followed periods of gently tapping its head and verbally urging activity every three hours. This seemed to work, with gradual improvement over two days, such that when the incubator was opened on March 21st, the young lizard was standing up with its frill out and appeared to be strong and healthy. However, it had a large kink in its tail, probably a result of the excessively high temperature early in incubation.

A second egg was observed to be slit on March 21st and the same process of removal from the egg, mouth-to-nose resuscitation and periodic "head tapping" was adopted over the following 48 hours which also produced satisfactory improvement in condition.

Both young lizards were placed in a purpose-built heated 700x700x700 mm wooden box, with the front wall angled and covered with screen mesh to maximise access to sunlight. A 60 watt light globe was fitted into the top and the enclosure was placed in a heated room at night to maintain 30-35°C. It was moved into direct sunlight for up to four hours per day. To avoid dehydration, the lizards were mist-sprayed with rainwater at least twice daily and were seen lapping water droplets off their noses by March 26th. At this stage, live moths and fruit flies were offered.

The first hatchling, with the kinked tail, was noticeably larger than its sibling, but much less active and showed no interest in food. In contrast, the second hatchling was observed actively and successfully hunting the live insect prey. Because of continued deterioration, it was decided to force-feed the first hatchling. This consisted of two people gently restraining the lizard and opening the jaws by pulling down the skin under the neck. A forefinger was then placed between the end of the jaws to separate them and a moth was placed inside. The lizard then ate and swallowed voluntarily. Water was also given at that time. Improvement was apparent the same afternoon, and the next day it caught its own food, drank when sprayed and displayed its frill when disturbed.

During the week of April 3rd - 9th it continued to thrive, drinking when sprayed and eating everything offered. It was seen drinking from a water dish on April 12th, but mist spraying is still continued at

least twice daily. As at the 7th September, 1994 the young lizards total length is 263 mm, it is very healthy and the most difficult part of its care is coping with its voracious appetite.

Unfortunately, however, the second hatchling deteriorated in a similar manner to the first. The same procedure of force-feeding and giving water followed, as it seemed that variation in physical condition could occur very rapidly. By the afternoon its condition had improved, but it was extremely lethargic over the next four days, barely holding its head off the ground. It was force-fed each day and on one occasion tried to catch its own food. However, the small grasshopper escaped each time, the lizard appearing too weak to grasp it firmly. On April 5th, it was making straining motions with its mouth, and on the 6th it regurgitated a force-fed grasshopper. The lizard was found dead on April 7th.

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A NOTE ON COLOUR CHANGE IN *DIPORIPHORA BILINEATA*

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Diporiphora bilineata displays considerable colour variation throughout its range (see photographs in Cogger (1992) pp 331, and Wilson & Knowles (1988) pp 214, 216) and as suggested by Cogger (1992) and Ehmann (1992) a complex of similar looking agamids may be involved.

On 30 January 1995, on a bright sunny day, Robert Browne-Cooper and I collected a mature *Diporiphora* sp. ? active on a stony slope among grasses in open Eucalyptus woodland at Petford on the western edge of Great Divide, Qld. The lizard was identical to Plate 65 on page 216 illustrated in Wilson and Knowles (1988) photographed by J. Wombey from Edward River, Qld, with pale head variegations and no dorsolateral stripes. Using Cogger (1992) we keyed it out as *D.bilineata*. It also complied with Wilson and Knowles (1988) statement: "Gular fold absent to very weak. Scapular and postauricular folds absent".

The appearance of the dragon we caught changed colour/pattern in the bag after several minutes to a *Diporiphora* that more closely resembled *D.bilineata*, as illustrated in Wilson and Knowles (1988) on page 214. The obvious changes were the development of the prominent pale dorsolateral stripes and loss of pale head variegations.

There is obvious potential for confusion for the field herpetologist based on current keys to the *D.bilineata* complex, and the recently observed ability of these dragons to change colour/pattern rapidly. Whether the changes are sex related, is not known but it is a probability. If the dragon was mature the other issues potentially affecting colour/pattern changes would be mood and temperature. Most herpetologists who find *Diporiphora* spp. in the field are normally confronted with the typical "two-lined dragon pattern".

I suspect, based on recent field observations and photographic evidence in recent publications, there are at least three taxa involved currently in *"D.bilineata"*. The field herpetologist should look at tympanic condition, in combination with scalation, age, sex (bright colours and pore development), temperature and mood.

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NEPHRURUS STELLATUS - OBSERVATIONS ON SPRING ACTIVITY

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On 17th August 1995, Colin Kranz and myself went to the dog fence approximately 5 km south of the Iron Duke mine site (33°29S, 137°07E) in the Middleback Ranges in search of the Stellate Knob-tailed Gecko, *Nephrurus stellatus*. The objective of this trip was to obtain photographs and specimens for a captive research project. This evening was chosen because the previous few days had day temperatures above 25°C. The area consists of sandy mallee scrub intermingled with spinifex.

On arrival at the site, 1830 hours, it was found that although the air temperature (chest height) was 24°C the ground temperature varied between 9 and 13°C. We walked along the fence for approximately 1.5km and returned via the adjacent bush for a total search time of approximately 1.75 hours. No reptile activity was observed even though some insect activity was detected.

On 24th August 1995, we again went to the same locality, arriving at 1840 hours. This time the ground temperature varied between 19 and 21°C with an air temperature of 24°C. Immediately on commencing our search insect activity in the form of cockroaches and scorpions was observed. At 1855 hours the first reptile was found, an adult *Lucasium damaeum* (Beaded Gecko). At 1900 hours the first *N.stellatus* was found (male adult) at a ground temperature of 19°C.

Over the next 1.5 hours a total of 20 specimens of *N.stellatus* (11 male, 5 female, 4 juveniles), 3 *L.damaeum,* and a juvenile *Ctenophorus pictus* (Painted Dragon, asleep in bush 150mm above the ground) were found. These specimens were observed whilst walking approximately 2km along the fence and back. At 2010 hours the ground temperature was still between 19 to 20°C while the air temperature had dropped to 15°C.

The highlight of the evening was the discovery of a mating pair of *N.stellatus* at 2005 hours (ground temperature 19°C) with another male *N.stellatus* approximately 1.5m away. After observing for approximately 4 minutes the pair parted and the female captured and retained as part of a captive research project. Mating occurred on a sparsely vegetated vehicle track which we had walked along 45 minutes earlier. The pair moved approximately 1.0m whilst coupled before separation occurred. Separation of the pair was probably initiated by our movements and the torch light.

Several interesting points regarding *N.stellatus* can be made from the observations made on this night. The high proportion of males present (approx. 3:1 male:female ratio) together with the inactivity a week prior, may indicate that *N.stellatus* males search for a mate immediately on becoming active in the warmer weather. This compares to a 1:1 ratio reported by Galliford (1981) in early April 1980 and a 1:1 ratio for *N.laevissimus* in late January (Delean and Harvey, 1981). Galliford (1981) also reported that *N.stellatus* did not appear to become active until approximately 1 hour after sunset whereas we observed the first specimen of N.stellatus half an hour after sunset at a ground temperature of 19°C. Mating of *N.stellatus* was observed at a ground temperature of 19°C compared to the temperatures reported by Annable (1992) of 24°C (*N.asper)* and 21.8°C (*N.levis*) in captivity.

The specimens of *N.stellatus* retained for further study will be the subject of further publications and so will contribute to a greater understanding of this species. Thanks to Colin Kranz for his assistance and advice.

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Book Review

CAPTIVE MANAGEMENT AND CONSERVATION OF AMPHIBIANS AND REPTILES

Edited by James B. Murphy, Kraig Adler and Joseph T. Collins

Published by the Society for the Study of Amphibians and Reptiles, and available from Dr R.D. Aldridge, SSAR Publications Secretary, Dept. Biology, St Louis University, 221 North Grand, St Louis, MO. 63103 USA
ISBN: 0-916984-33-8, 413pp., hardback, US$58.00

This impressive book is based on the 1991 symposium, "Captive Management and Conservation of Amphibians and Reptiles", sponsored by the Society for the Study of Amphibians and Reptiles (SSAR) and the Herpetological League, and held at Pennsylvania State University. The symposium was dedicated to Dr Roger Conant, Director Emeritus of the Philadelphia Zoo, "in recognition of his many contributions to the growth of herpetology in North America, including the development of captive management programs ...". Such acknowledgement is particularly appropriate and, indeed, one of my first herp books was Conant's 1958 "Field Guide to Reptiles and Amphibians of the North-eastern States" - it is still on my shelves.

The book's contents are presented in six main sections. "Dedication and General Issues" opens with an overview of Conant's career. Mittermeier and Carr review conservation of reptiles and amphibians from a global perspective and call for more planning, training, education and integration with other conservation efforts. Similar sentiments are expressed in a consideration of the role of zoos and aquaria.

"Management Issues" commences with brief overviews of the light and temperature requirements of captive herpetofauna; both highlight the complexity of these parameters and suggest areas of further study. There is an interesting chapter on chemoreception in reptile feeding behaviour, including a very useful table on scenting materials developed by zoo herpetologists. The two presentations on nutrition in carnivorous and herbivorous reptiles highlight the need for more research to address practical feeding problems, and consider the role and impact of artificial diets and nutritionally-balanced feeds, particularly as they relate to breeding programs. Swingland overviews conservation of testudinids and calls for a more scientifically rigorous approach to both *in situ* and *ex situ* programs, together with the necessary long-term support.

Appropriate veterinary procedures for the acquisition and release of captive-bred herpetofauna are critically important. Greater attention is needed to quarantining and monitoring newly-acquired animals before their introduction to the main collection and, of particular importance, a strict breeding, quarantine and evaluation process for those individuals destined for release as part of conservation programs.

Underlying themes in the "Reproductive Biology" section are the need to understand wild populations and apply the key points, and follow an integrative approach. Moore discusses the complexities of exogenous and endogenous factors controlling reproductive factors in amphibians, while Crews *et al.* focus on three factors affecting reptilian reproduction - the specific behaviours of conspecifics, influence of embryonic experience on adult phenotype, and manipulation of sex ratios (with particular reference to TSD). Appended to a consideration of an ethological approach by Chiszar *et al.* is a bibliography of over 600 papers from four journals in the decade 1980-90.

The adaptive capacity of reptiles is covered in three papers, the first discussing the potential value of phenotypic plasticity in reptiles to captive breeding programs, using two US colubrids. A second chapter reviews methods for manipulating clutch size in lizards and discusses the effects on wild survival and implications for captive programs - both are bases for serious consideration. The last in this series summarises evidence of non-lethal effects of temperature, moisture and oxygen

tension on developing embryos of oviparous reptiles, and presents a simple protocol for incubating eggs in management programs.

In a chapter that does not sit comfortably in Reproductive Biology, Brazaitis and Wise analyse the trade in crocodilian skins to examine the conservation of commercially important reptiles, including the vexed question of sustainable use. They conclude that most wild populations are not being properly protected and that the illegal trade continues to grow.

The disparity of effort directed towards amphibians and reptiles is yet again reflected in this publication - five presentations on "Model Amphibian Programs" versus thirteen for reptiles. The former commences with a brief overview of the unusual caecilians, emphasising their ease of maintenance but our paucity of knowledge. Another relatively unfamiliar group for Australasian herpetologists, salamanders, is examined in some detail through presentation of what is needed to establish and maintain a successful colony; including a very useful table of disease symptoms and treatments based on 30 years of study at Cincinnati Zoo.

There are more threatened bufonids than any other amphibian group. Johnson reviews conservation programs for four such toads that exemplify a range of management options which integrate *ex situ* and *in situ* initiatives - Houston Toad, Natterjack Toad, Wyoming Toad and Puerto Rican Crested Toad. Importantly, all involve habitat support.

Poison Arrow Frogs have two chapters - the first, another comprehensive review by the Zimmermanns of reproductive strategies, breeding and conservation of "Dart - Poison Frogs and Malagasy Poison Frogs". The second is an equally valuable summary of management and breeding of dendrobatid and neotropical hylid frogs at the National Aquarium in Baltimore, where repeated successful breeding of 19 species of dendrobatids and four hylids has been achieved. The authors of both chapters have clearly set the standards for management of these stunning little frogs.

The 13 chapters in the section on "Model Programs for Reptiles" comprise two on chelonians, six on lizards, four on snakes and one on tuatara. Mike Goode leads off with a detailed coverage of reproduction in three kinosternid turtles at Columbus Zoo extending over 14 years. Twenty five years of breeding, rearing and repatriation have brought most of the endangered Galapagos Tortoises and Land Iguanas back from the edge of extinction, but as Cayot *et al.* note, much work remains to be done.

There are two short papers on the management of Day Geckos, followed by two more extensive presentations on the captive management of, and genetic variation in the Piebald Chuckwalla. A review of reproduction in the Prehensile-tailed Skink and Panther Chameleon complete the lizard chapters.

Tolson reviews Toledo Zoo's successful program for insular boids in the genus *Epicrates* and there is a short report on boid management at the National Zoological Park. An overview of the integrated *in situ - ex situ* program for the Aruba Island Rattlesnake is presented, including management of the Paramyxovirus issue. The model program section closes with an examination of the role of artificial refugia in enhancing snake habitats, and the role that captive breeding is playing in Tuatara conservation in New Zealand.

In the penultimate chapters in "Future Directions", the role of the private sector is reviewed and a stronger conservation focus is called for from zoo herpetologists. An important role of universities is seen as providing and promoting multidisciplinary approaches. In the final chapter, Wise summarises capture and restraint techniques of captive crocodiles.

Having moved away from direct management of herpetofauna over the last few years, I enjoyed bringing myself up-to-date with the work of some of the world's leading herpetologists outside Australia. The book is full of very useful information, much of which can be applied to our circumstances and programs. It is very well edited and, at US$58, is certainly not overpriced. I recommend it to anyone involved in the captive management and conservation of these fascinating creatures.

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Director, Conservation Programs, Zoological Board of Victoria.

NOTES TO CONTRIBUTORS

Herpetofauna publishes original articles on any aspect of reptiles and amphibians. Articles are invited from any interested author; encouragement is given to articles reporting field work and observations.

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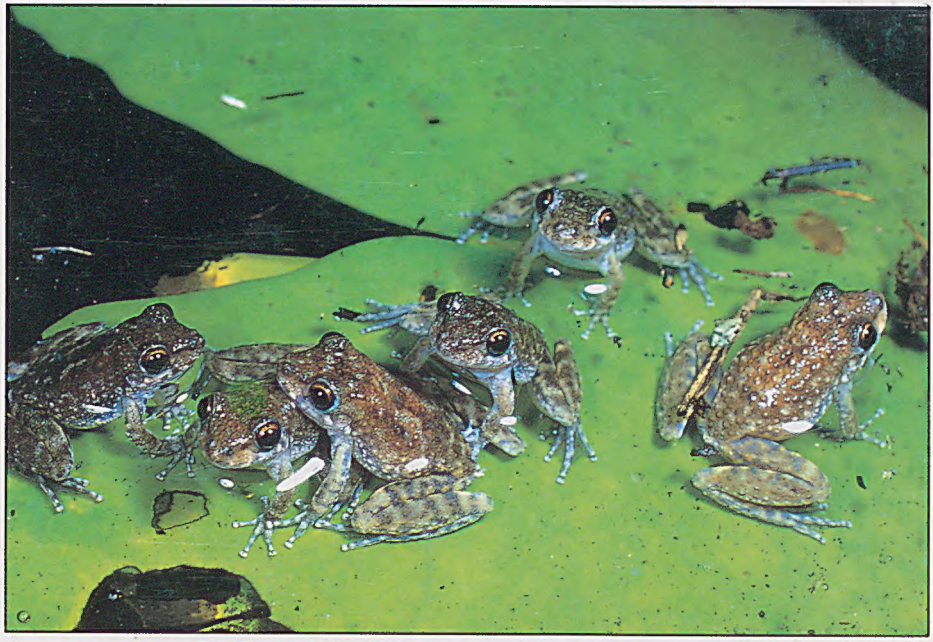
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The Rockhole frog (*Litoria meiriana*) from Nourlangie Rock
See paper on page 17. (photo: H. Cogger)



Giant cave gecko (*Pseudothecadactylus lindneri*) from Nawalandja, Kakadu National Park.
See paper on page 53. (photo: G. Husband)